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Newton

The year 1942 marks the tercentenary of the birth of SIR ISAAC NEWTON, England's most brilliant scientific genius and *primus inter pares* of the greatest men of science of all time. It is fitting that, even amid the stress of war, we should pause for a moment to pay tribute to the memory of one who, 'had he flourished in ancient Greece, would have been worshipped as a divinity.' In the pages of a scientific journal there is no need to detail Newton's contributions to optics, mechanics, astronomy, and mathematics, for they are already familiar. We may, however, profitably recollect that they had such a radical effect upon the progress of science as to influence materially the subsequent course of civilization. Newton also interested himself in chemistry, and his views are discussed by DR DOUGLAS MCKIE in our present issue (p. 141).

Newton's principal characteristic was perhaps his invariable habit of thinking for himself, whether in science, in philosophy, in theology, or in the mundane matters of daily life. Possessing a phlegmatic temperament, lacking a sense of humour, and uninterested in music, poetry, and art, he was 'notoriously susceptible to the challenge of a problem' and fertile in the use or invention of mental and material tools for its solution. As need arose, he could both elaborate a new branch of mathematics—the calculus—and construct with his own hands an efficient reflecting telescope. He was, in fact, a resourceful as well as a profound thinker, with little of the eccentricity of character that frequently accompanies genius. The picture drawn of him by a modern English poet:

> Obscure, unknown, the shadow of a man
> In darkness, like a grey dishevelled ghost,
> Bare throated, down at heel, his last night's supper
> Littering his desk, untouched; his glimmering face
> Under his tangled hair, intent and still,
> Preparing our new universe—

is only partially true. He was neither obscure nor unknown; on the contrary, his supreme scientific insight was recognized instantly in England, and very quickly on the Continent of Europe. LAGRANGE described the *Principia* as the greatest production of the human mind, a verdict endorsed by LAPLACE. Moreover, Newton's power of abstract thought did not mask the fact that he possessed shrewd business ability, a talent for organization, and a forceful determination. These qualities he showed in no uncertain manner in his reforms at the Royal Mint, which he carried out with firmness of purpose and scorn for attempts at bribery. 'The ability, the industry, and the strict uprightness of the great philosopher,' says MACAULAY, 'speedily produced a complete revolution throughout the Department,' and the urgent task of recoinage was successfully accomplished. As an instance of the efficiency of Newton's work, it may be mentioned that in a very short time he increased the weekly output of silver specie from £15,000 to £120,000. From the devoted disciple of science, Newton had become the faithful servant of the State, so to remain until his death at the age of 84.

In addition to his scientific and technical activities, Newton represented the University of Cambridge in Parliament for some years, though he never attained eminence in politics. He was President of the Royal Society for nearly a quarter of a century, and one of the eight Foreign Associates of the French Academy of Science.

For us today it is salutary to recall the 'rules of reasoning in philosophy' laid down by Newton in Book 3 of the *Principia*. They are fundamental and inescapable now as when they were first enunciated in 1687; and strict adherence to them would swiftly dispel the miasma of unfounded

hypothesis that still from time to time vitiates the atmosphere of science:

I. *We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.*

II. *Therefore to the same natural effects we must, as far as possible, assign the same causes.*

III. *The qualities of bodies, which admit neither intensification nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.*

IV. *In experimental philosophy we are to look upon propositions inferred by general induction from phenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phenomena occur, by which they may either be made more accurate, or liable to exceptions.*

Newton himself never swerved from this austere discipline, which controlled the dynamic energy of his thought. Let men of science 'rejoice that so great a glory of the human race has appeared,' and subject themselves to the same intellectual austerity.

Correspondence

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

CO-OPERATION BETWEEN UNIVERSITIES AND INDUSTRIAL TECHNICAL STAFFS

From 'Naturalized'

The closer co-operation between universities and industrial laboratories, for which PROFESSOR ANDRADE appeals in his letter (this Journal, Vol. I, No. 1, p. 7) could be favourably promoted by working up both types of institution thoroughly, a mutual exchange of activities by their staffs. I had good opportunity to observe some results of such an exchange during my employment at various German universities in their 'democratic' period (1918–33). There, it was quite common for a substantial fraction of all specialized lectures at universities, and especially at technological faculties, to be delivered by members of the staffs of various research laboratories. These lectures provided a valuable supplement to the standard teaching programme in a more practical and specialized direction, and gave an opportunity to students who intended to go into industry of becoming familiar with recent industrial methods. Moreover, by the regular presence of industrial lecturers at the universities a personal contact was established with the university staffs. This contact frequently led to discussions of technical problems which sometimes gradually developed into regular consultations by a university professor.

Germany was in no way unique in these developments. America has, and Holland had, progressed still further in this direction. The closest co-operation between universities and industrial technical staffs is probably achieved in the U.S.S.R. Where such co-operation has been tried, it has never been abandoned. In the present emergency, our war industries are supported by all the skill and devotion which the staffs of our universities can offer. Scientific and industrial relations have thus moved into a particular type of close co-operation, and this, we may hope, will be developed into a suitable permanent form after the war.

SULPHAPYRIDINE

From L. P. Garrod, M.A., M.D., F.R.C.P.

In my article on 'Progress in Bacterial Chemotherapy' in your last issue (Vol. I, No. 3, p. 122) it was stated that sulphapyridine (M. and B. 693), the drug which has brought pneumonia within the effective scope of chemotherapy, was synthesized by A. J. EWINS. It has been pointed out to me that DR M. A. PHILLIPS was the co-discoverer of this drug with Dr A. J. Ewins, their names being associated in the literature and patents relating to it. I much regret that Dr Phillips's name was omitted in my reference to this discovery.

RUSSIAN-ENGLISH TECHNICAL DICTIONARY

From Sir John Russell, F.R.S., *Chairman, Anglo-Soviet Scientific Collaboration Sub-committee, British Council*

There is an urgent demand at the present time for an up-to-date Russian-English dictionary of scientific and technical terms. It is known that a number of Russian-English glossaries of specific terms have been compiled by various scientific institutions and individuals, and it is thought that it would be extremely helpful to scientists and technical translators if copies of these glossaries could be collected together and placed in the Science Library in London, where one complete set could be consulted.

Will, therefore, any institution or individual who has compiled a glossary of Russian scientific or technical terms, whether printed or in MS., please send a copy to the Secretary, Anglo-Soviet Scientific Collaboration Sub-committee, The British Council, 3 Hanover Street, London, W.1, who will collect these for the Science Library?

It is hoped at a later stage to compile a large dictionary, but the immediate aim is to collect the different glossaries in one place where they can be consulted. Each glossary will be known by the name of its compiler.

British animal husbandry

JOHN HAMMOND

British animal husbandry is celebrated the world over. Originally an art practised in the light of a shrewd though empirical judgment, the breeding of animals to meet definite requirements and conditions is rapidly becoming a science. Dr John Hammond, who has himself done much to effect this development, explains some of the breeders' aims and the methods by which they are attained.

HISTORICAL

Pioneer Breeders

The first efforts to breed superior animals were made by individual breeders, such as those by ROBERT BAKEWELL with Longhorn cattle (1750) and Leicester sheep (1755), by JOHN ELLMAN with Southdown sheep (1778), and by CHARLES and ROBERT COLLING with Shorthorn cattle (1780). Their methods were, first to collect the best animals they could for the purpose they had in view, and then to breed the best to the best. This involved in most cases close breeding and in many cases a considerable amount of intensive in-breeding [22].

That is, having decided on the type of animal they wanted, they concentrated in their herds and flocks the germ-plasm of the animals which showed these characters in greatest degree.

The Herd-books

As the reputation of their superior stock spread, others came to purchase their cattle and establish herds of these improved animals in different parts of the country. The danger then appeared that the blood, or germ-plasm, of these superior animals would be so diluted by crossing with inferior stock in the now widely distributed herds that it would be swamped, and the pioneer work in concentrating the best germ-plasm destroyed. In 1822, therefore, the first of the herd-books—*Coates' Herd-book for the Shorthorn Breed*—was instituted to record the pedigrees of all animals which traced in direct line to the original superior animals, and so to continue the idea of the pioneer breeders, viz. to concentrate the germ-plasm of the best animals. These herd-books, and the breed societies which eventually ran them, then set up standards of excellence for the breed in order to attempt to define in words the object for which the animals should be bred and selected, that is to get all the breeders to have the same objective in view. Needless to say, the world is never static and commercial requirements change with time; standards of excellence therefore have been changed slightly since their institution. Moreover, certain individual breeders from time to time, even within the framework of these herd-books, had ideas of their own as to how the evolution of the breed should proceed, and, although the pedigree was continued, they picked out and concentrated in like manner certain types which they considered better suited to the times in which they lived. Thus, concentrations of germ-plasm of rather different types were produced in Shorthorn cattle, by the same in-breeding methods, by the BOOTHS (THOMAS, JOHN, and RICHARD), by THOMAS BATES, and by AMOS CRUIKSHANK in turn.

The Show-yard

Another method by which uniformity of purpose by breeders within the herd-book was achieved was by the show-yard system. Under this system breeders of outstanding ability were asked to select and give prizes to those animals which most nearly approached the ideal to which the efforts of the breeders were directed. All the breeders in the herd-book society were thereby given a visual demonstration of the objective towards which they should strive. The first of these shows was for fat stock, that of the Smithfield Club, founded in 1798 [1]. One of its purposes was to develop early maturity in livestock, thus forwarding the interests of both feeder and butcher. How well it did this is shown, for example, by the fact that at the 1874 show the best Devon steer, weighing 1,680 lb., was 4 years old, whereas at the 1925 show the best Devon steer weighed 1,669 lb. at 2 years 10 months old.

In 1837 the Royal Agricultural Society's Show was founded for breeding stock. A large number of local and county shows now serve as preliminary

rounds for this premier event of the breeder's year. One criticism [19] which has been made of these shows is that fancy points, such as colour, shape of horns, etc., received too much attention. These characters, which are for the most part of the simple Mendelian type of inheritance [6], form the 'trade mark' of the breed and are a guarantee of its purity, for, with our present-day knowledge of inheritance, their appearance reveals any admixture of outside blood. Some criticisms of the show-yard [19] seem to imply that it is the only method of livestock improvement adopted by breeders, whereas in fact, as the present article will show, it is only one link in the chain of methods employed.

Production Tests

In order to ensure that the various breeds of livestock were bred to suit commercial requirements, tests of production were instituted at the shows. The Smithfield Club [1] has kept complete records of carcass tests for meat-producing animals since 1895, the classes being judged by butchers to ensure that the improvement of the animals followed the changing tastes of the public for quality in meat. Some breed societies, such as the National Pig Breeders' Association, have run their own carcass tests for bacon and for pork, these being judged on a score-card system so as to show those who do not win prizes in what respects their animals are failing to meet trade requirements. Similar tests for bacon carcasses have been held at the London Dairy Show since 1922. Some breed societies, too, such as the Large White, keep fecundity records of their sows. For dairy cattle, milking trials were instituted at the principal shows, those at the London Dairy Show having been held annually since 1876 [12]; similar tests are also carried out at the Royal Agricultural Society's Show [13].

To assist breeders to select their cows for milk production, lactation milk yields of cows were recorded by owners and breed societies, the Ayrshire and Jersey being among the first of these to operate. Later, in 1910, a uniform system of milk recording throughout England and Wales was instituted by the Board of Agriculture, and registers were compiled of cows with consistent high production; butter-fat tests were also made. In addition, the actual quantity and quality of the butter produced by individual cows have been tested at the Dairy and Royal Shows; thus, besides fat percentage, other factors are considered such as size of fat globule and the colour of the butter, of special interest to the butter-producing breeds like the Jersey and Guernsey.

In recent years scientific workers have been trying to devise methods for measuring more accurately the various factors which go to make for quality in meat and dairy products, so as to facilitate the work of the breeder in selecting his stock.

Progeny Tests

It was a practice among the pioneer breeders to 'let out' some of their young bulls or rams each year to other breeders, so as to be able to see the quality of their progeny before they used these sires on their own selected females. This 'progeny testing' of sires, which is now widely advocated on the basis of genetic experiments [6], was later introduced into the show-yard, where, at the Royal and Dairy Shows, prizes were given for a collection of animals the progeny of a single bull. Another form this progeny testing has taken is the publication of the names of the sire and dam of animals winning in the carcass tests at shows, such, for example, as those in the Large White Herd-book. Registers of merit for bulls which have produced a given number of daughters of outstanding merit are published by the Dairy Shorthorn, British Friesian, Jersey, Guernsey, and other herd-books. Recent advances in the science of artificial insemination have now made it possible greatly to extend the use of such progeny-tested males and so spread the best germ-plasm widely throughout the breed [23]. For example, not only can some ten cows be inseminated from a single ejaculation by a bull, but by storing the semen at low temperature and preventing exposure to the air, it can be sent by air mail over long distances, so that cows in Holland and ewes in Poland have conceived to sires in England [4] [24].

Advanced Registers

As long as the destinies of the breed are in the hands of a small number of breeders it is comparatively easy to keep up a high concentration of the best blood and germ-plasm within the breed; such breeds have shown a rise in the coefficient of in-breeding, i.e. the percentage of actual out of potential ancestors in the pedigree [2]. When, however, the breed is in the hands of a very large number of breeders, some of them inexperienced, it is a much more difficult matter to know where the best germ-plasm is to be found. To overcome this difficulty some

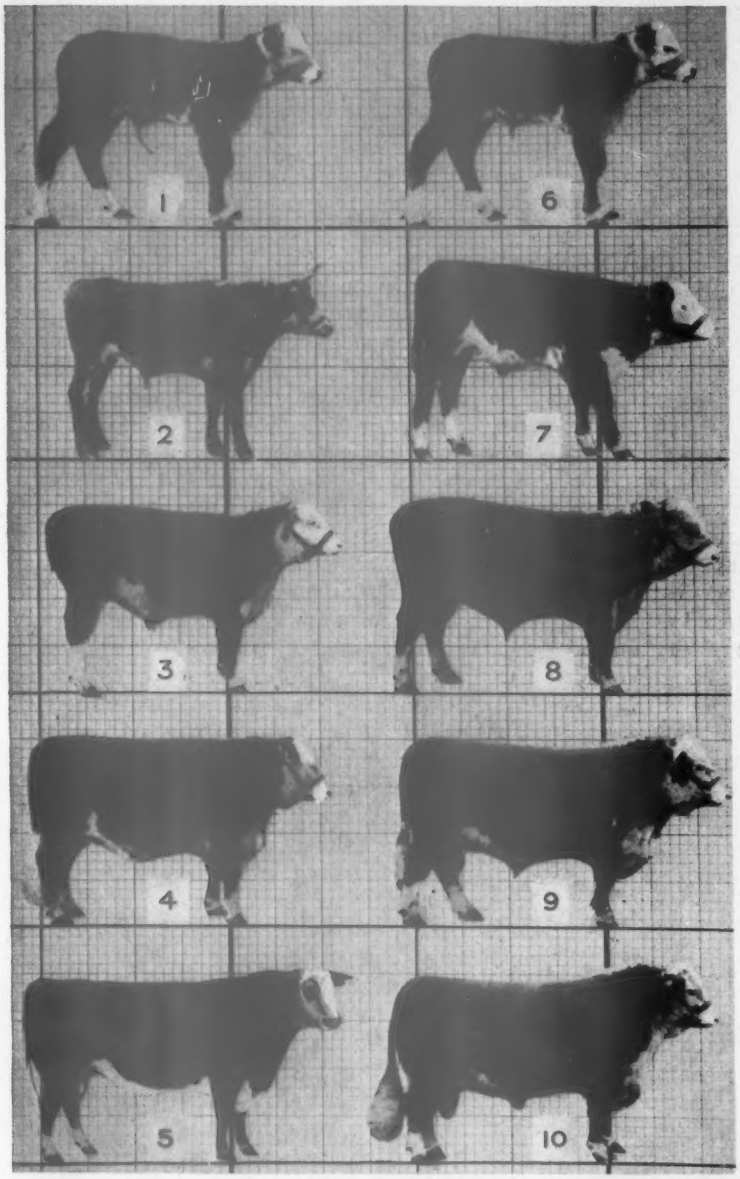


FIGURE 1 – *Changes in the body proportions of Hereford cattle. In order to show changes in proportions, as distinct from size, all the photographs are reduced to the same height at the shoulders.*

1. Heifer, 2 days.
2. Steer, 30 months, grown on low level of nutrition.
3. Steer, 11 months, grown on high level of nutrition.
4. Steer, 22 months, grown on high level of nutrition.
5. Bull of 100 years ago.
6. Heifer, 2 days.
7. Bull, 5 weeks.
8. Bull, 13 months.
9. Bull, 22 months.
10. Bull, 5 years.

herd-books (British Friesian, Jersey, Guernsey, etc.) have started Advanced Registers, or Registers of Merit, that is, registers of animals which have outstanding records of performance, so that they can be used for breeding bulls. This is also achieved in another way by the Dairy Shorthorn Society, which does not allow a bull to be registered unless the dam has yielded more than a given amount of milk.

OBJECTS OF BREEDERS

The very many breeds that exist in Great Britain are the result of the interactions between two main objects that the breeders had in view—a breed for every purpose and a breed for every type of environment. Thus in cattle, for example, there are breeds for beef production—the Beef Shorthorn, Hereford, Aberdeen-Angus, etc., for good lowland environmental conditions; and others—the Galloway, Highland, and Welsh—for cold rough mountainous conditions; breeds for dual purposes (milk-beef), the Dairy Shorthorn for good land and the Red Poll for poor light dry land; breeds for milk, the Ayrshire and British Friesian; and breeds for cream and butter, the Jersey and Guernsey.

With sheep the breeds range from the Welsh and Blackfaced—improved mutton breeds suited for wet and cold mountainous districts—to the Hampshire and Suffolk, improved fat lamb breeds suited to arable areas growing crops for folding purposes.

The various breeds have thus been closely adapted to the conditions under which they are to live and have, therefore, in addition to production, a quality called 'constitution,' that is, the power to live long and thrive under these conditions, a quality without which long-continued high production is not possible [5] [6].

BREEDING METHODS

In breeding for a purpose the breeder must be

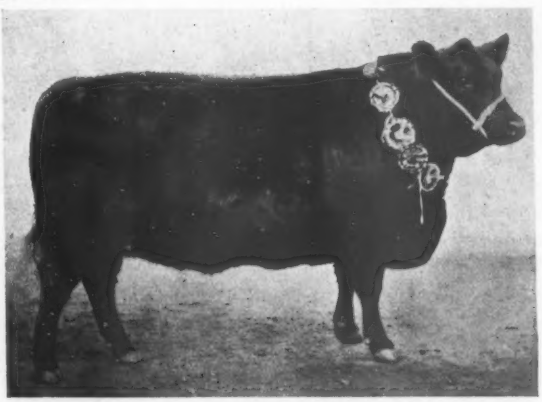
in close touch with those who are using his product commercially, and this has been done by the methods already outlined. He also has to study the effects of environment, feeding, and the different conditions of management on the amount and quality of the product he is breeding for. Having found the optimum conditions, he arranges to breed and select his animals under these conditions, so that he is then able to pick out and breed from those animals which show in the highest degree the qualities he is striving after. By this means he is able to direct the evolution of his breeds. In any but optimal conditions for production, the production is limited by the environment or food supply and not by the genetic capabilities of the animal; hence proper genetic selection cannot be made. Thus it will be seen that the breeding methods are not merely static, in reproducing the best which has gone before, but evolutionary, in raising the level of production and quality to higher levels than ever existed previously. For this purpose the breeder not only uses the results of the science of genetics, which enable him to eliminate unwanted characters, concentrate the germ-plasm of desirable animals, and pass this on to future generations with a high degree of certainty; he also employs the results of the sciences of animal nutrition and animal physiology, which tell him what are the optimal conditions for the production by the animal of the qualities he desires to breed for. Examples of the way in which these are used will be given below.

Beef

For beef purposes the butcher requires an animal which will yield him a good percentage of carcass, i.e. one in which the proportions of offal parts such as head, legs, intestines, etc., is small, one which has a great thickness of muscle as compared with length of bone, and one with a smooth covering of fat over the whole carcass. These things develop as the calf grows up, and the extent to which they develop determines the value of the animal for meat purposes. That is, as the animal grows up it not only increases in size, but also changes in the proportions and composition of its body (see figure 1).

At birth the calf is all head and legs, while as it grows up the loin and buttocks grow at a faster rate than the head and legs, and so the more valuable parts increase in proportion to the offal parts. If the animal is reared on a low plane of nutrition, however [20], it grows up without much change in body proportions and so has a poor meat value (compare Nos. 2 and 4, figure 1). This is because the early-maturing parts of the body—head, legs, bone, heart, liver, and lungs—have first call on the nutritive substances available; thus on a limited food intake these parts continue to grow, while the growth of the later-developing and more valuable parts, such as the loin and buttocks, is inhibited. Localities, therefore, such as range areas, where the conditions of nutrition are uncertain, are unsuitable for breeding improved strains of beef cattle; under such conditions, full development of the genetic possibilities of the animal for meat production is not possible and proper selection cannot be made. On the other hand, in good grassland areas or in districts where plenty of supplementary feeds are available, it is possible to push forward the animal to full development of its meat qualities. By doing this with successive generations, and selecting and breeding from those which prove best, the proportions of the body develop not only at an earlier age but also to a further extent. Thus the adult Hereford bull of 100 years ago (figure 1, No. 5) is no more advanced in its body proportions than is a present-day bull at a year old. In the opinion of the judges at the Smithfield Show the Aberdeen-Angus is the nearest approach yet obtained to the ideal beef conformation (figure 2).

FIGURE 2 – *Aberdeen-Angus heifer of ideal beef conformation.*



Mutton and Lamb

How the British breeds of livestock have been improved for early maturity can be seen by comparing the changes in proportions which occur in the growth of the wild sheep, the Mouflon, with those

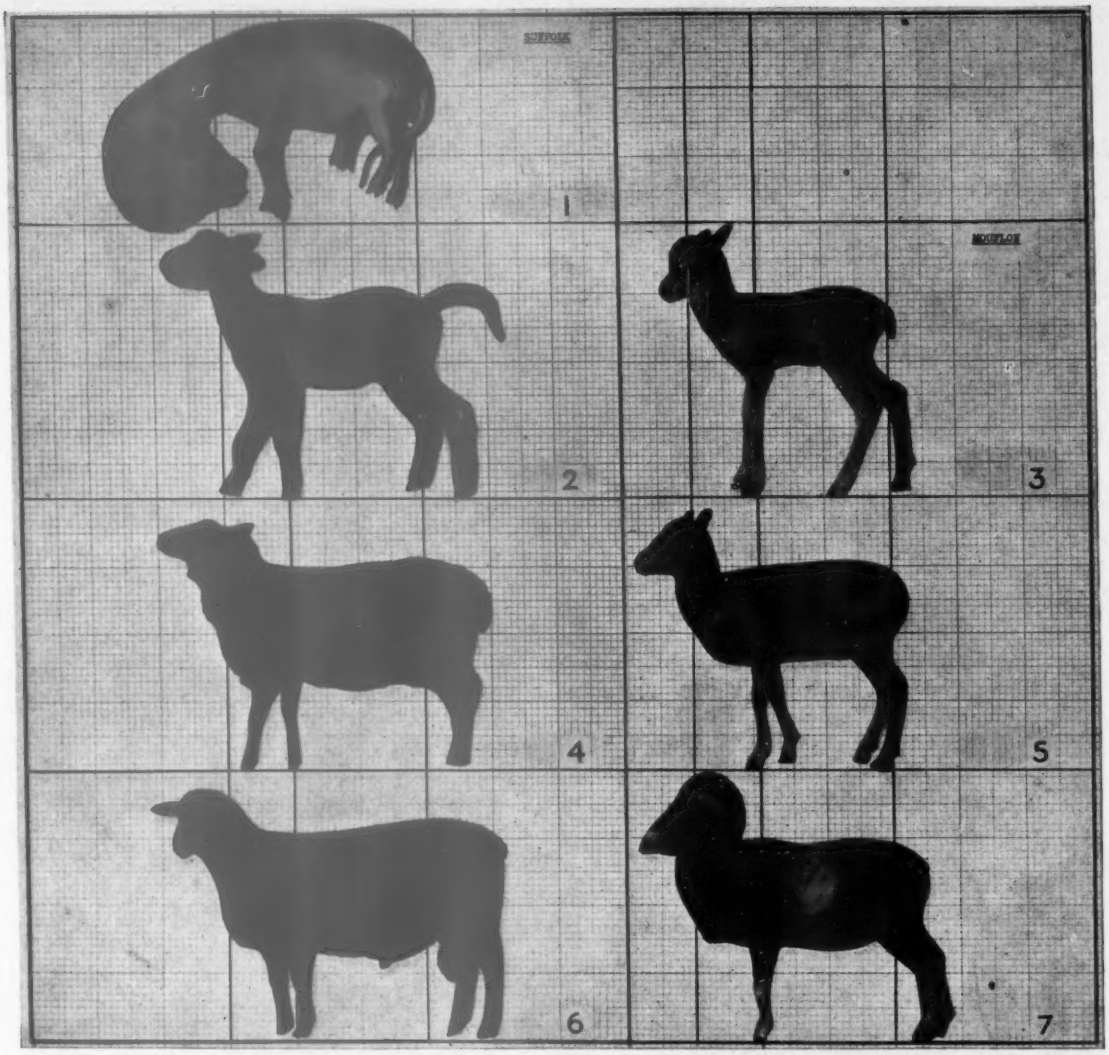


FIGURE 3 – *Changes in the proportions of the improved Suffolk* (left) *and unimproved Mouflon* (right) *breeds of sheep as they grow up. Each is reduced to the same shoulder height so as to show differences in proportions as distinct from differences in actual size.*

Top: Embryo of 2 months *Second line:* 4 days old. *Third line:* Adult ewe. *Bottom:* Adult ram.

which occur in an improved breed like the Suffolk (figure 3).

Early maturity from the butcher's point of view is not merely increase in weight for age, but consists of a speeding-up of the changes occurring in the proportions of the body. From the butcher's standpoint the animal is not fit to kill until the proportion of fat and muscle to bone reaches a high level; this ratio is closely related to the shape and proportions of the animal, and so he uses visual appreciation of shape as a guide. For example, an animal *shaped like* the Suffolk lamb at birth (figure 3) yields for every 100 lb. of live weight only 31 lb. of edible muscle and fat, whereas one *shaped like* the adult Suffolk ram yields double that amount, viz. 62 lb. [7]. From figure 3 it will be seen that the shape of the adult Mouflon ewe—and so its yield of edible meat—is only a little in advance of our improved breeds at birth. That is, we have increased the early maturity of improved breeds so that at about 2–3 months old they will yield as much edible meat as the unimproved sheep in adult life. As previously explained, under Beef, all this has been

done by rearing the animals on a high plane of nutrition and by picking out and breeding from those animals which are the most early-maturing, i.e. those in which the changes in body proportions occur most rapidly. In this way British breeders have not only obtained more early maturity, but have pushed forward the development of meat qualities in the adult animal to higher levels than have ever been reached before. All this has involved a considerable amount of trouble and expense in growing special crops for folding, etc., and in finding foods which would increase the rate of growth—especially in the ram lambs, for one good ram can leave many more offspring than one good ewe. These general principles, as illustrated by the above example, apply also to cattle and pigs bred for meat purposes.

The breeder of livestock has to keep in close touch with prevailing trends in the public demand for quality in meat. This, as mentioned above, is ensured by appointing butchers as judges at the carcass tests at shows. Recently, however, overseas breeders who are unable to exhibit at shows in Britain have required some guidance in this matter, and standards of excellence for carcasses on the score-card system have therefore been evolved to meet their requirement [9] [11] [16]. They can consequently run carcass tests, based on the British public's demand, in shows in their own countries. Figure 4 illustrates one example of such standards for lamb, for which the great demand is now for carcasses of 28 to 36 lb. Ideal and unsuitable carcasses are illustrated in the score-card system produced by the Australian Meat Board.

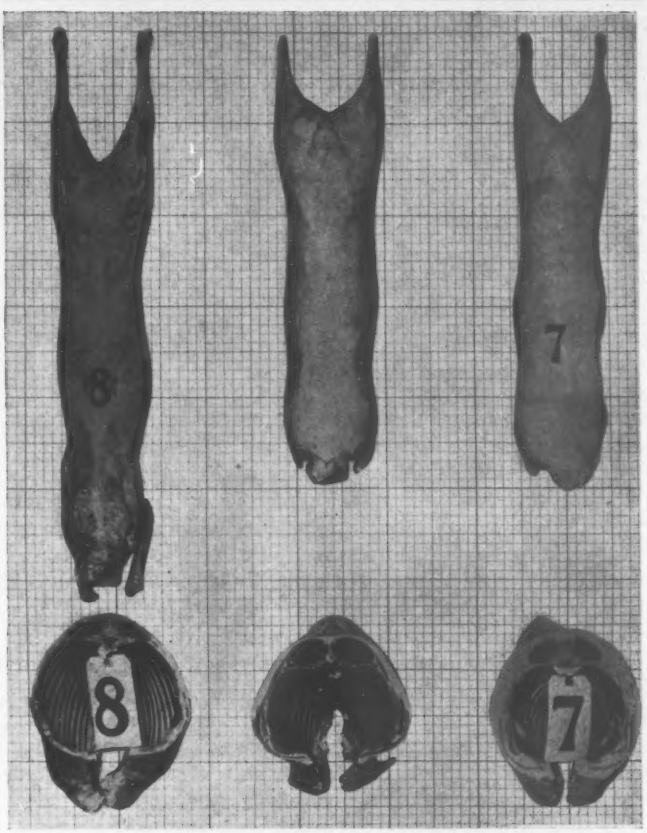


FIGURE 4 – *Lamb carcasses of 28-36 lb., illustrating the method of combining photographs with score cards to show breeders the requirements of the meat trade.*

Pts.		*Unsuitable*	*Suitable*	*Unsuitable*
	EXTERNAL:			
1.	Legs, short boned and well filled ..	1	30	21
2.	Fat covering sufficient on lower part of legs	2	10	10
3.	Loin, wide and full	3	10	6
	INTERNAL:			
4.	Depth of fat over loin, correct proportions	5	20	8
5.	Eye—muscle, depth and size	4	15	7
6.	Ribs, light with high proportion of lean	5	10	2
7.	Colour of lean, not too dark. Texture of lean, fine grained	2	5	5
	Total	22	100	59

As previously stated, the breeder has to make selection of his animals under the conditions which best develop the characters he is breeding for. Scientists have been at work to discover what these are, and one example can be given of the optimum conditions suited for the production of fat lamb carcasses of 30 lb. VERGES [21] fed lambs from the third month onwards of foetal life (by controlling the food intake of the pregnant ewe for two months before the birth of the lamb) so as to make their growth-curves conform to certain predetermined curves (see figure 5).

Those which were caused to grow as quickly as possible reached the required 30 lb. carcass weight in 56 days (figure 6, No. 47) and made the most suitable carcasses—short-boned with great depth of flesh; while those which were caused to grow slowly reached the required 30 lb. carcass weight in 294 days (figure 6, No. 38) and produced the worst carcasses, with long bones and

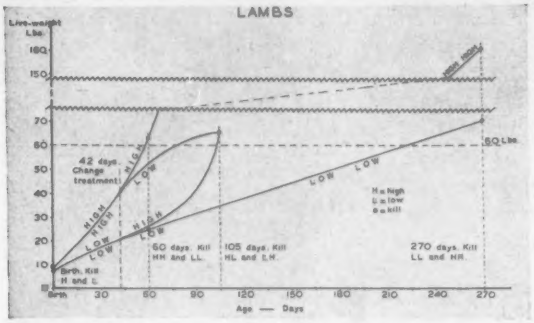
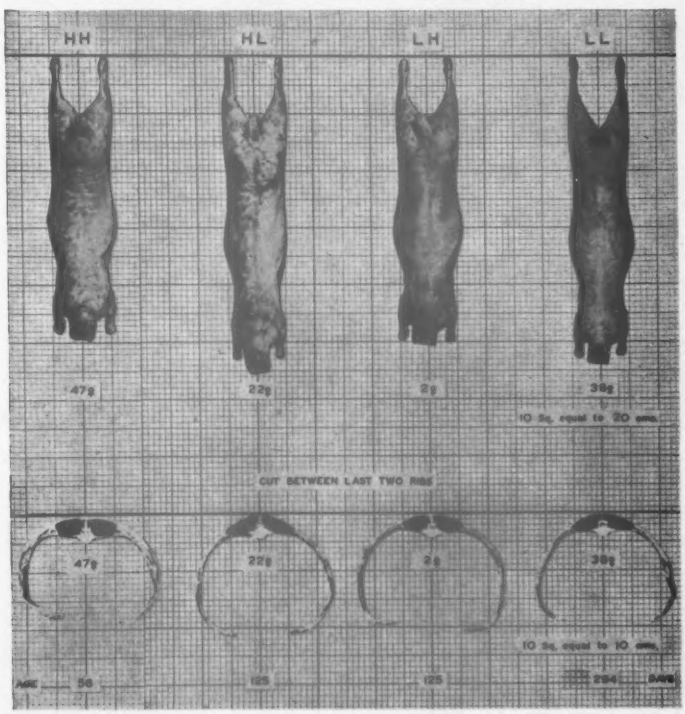


FIGURE 5 – *Plan of Verges' experiment with lambs to determine how the shape of the growth-curve, controlled by feeding on different planes of nutrition, can affect the proportions and composition of the carcass. Carcasses of lambs with these four different types of growth-curve are shown in figure* 6.

but thin flesh over them. The second-best carcass was made by those which grew slowly at first and were then finished quickly (figure 6, No. 2) at 125 days old. Those which were killed at the same age, but had been made to grow quickly at first and finished slowly, gave the second-worst carcasses (figure 6, No. 22). They grew a large frame, but the poor rate of growth towards the end of the feeding period prevented a sufficient covering of flesh and fat. No. 47 (figure 6) is typical of the optimum conditions for those who are breeding for fat lamb production (cf. figure 4), while No. 2 is typical of the optimum conditions for those who are breeding for mutton production.

The problem of evolving improved breeds of mutton sheep for cold, wet, mountainous, and poor land areas is much more difficult, for in addition to improvement in meat quality the breeder must develop hardiness of constitution in his animals. The British breeder has always striven to breed all his animals with good constitutions, and those destined for mountain areas form a special case. On the one hand, selection for hardiness cannot be obtained without keeping the animals under the appropriate severe conditions, and, on the other hand, selection for improved mutton qualities cannot be obtained unless the animal is reared on a high plane of nutrition. Breeders of such sheep as the Welsh and Blackfaced therefore breed and select their ewes under the rigorous climatic conditions of the mountains, but breed and select their rams in small flocks kept under better nutritive conditions. By using such rams on hill flocks and selecting their progeny for hardiness, a combination of hardiness and improved mutton qualities has been obtained. Breeding sheep and cattle suitable for the hot, humid conditions of the tropics, however, has not been possible, for the climate has not been available in Britain. Cattle bred under temperate climates are liable to a raised metabolism and so to lowered production under tropical conditions [17]. Crosses between these and Zebu breeds which have been evolved in the tropics are therefore being undertaken to build up breeds suited to tropical conditions [8] [14].

FIGURE 6 – *The effect of the shape of the growth-curve (see figure* 5*) on the carcass proportions of lambs at the same carcass weight* (30 *lb.*). *Compare these with the requirements of the meat trade (figure* 4).



Pork and Bacon

The development of breeds of pigs for pork and bacon has followed much the same lines as in other animals. The present demand for pork carcasses is mainly for those pigs of about 100 lb. live weight, while for bacon a heavier pig of about

200 lb. live weight is required. The problem has thus been to breed pigs which would provide carcasses with the correct proportions of muscle, fat, and bone at these weights. For example, the Middle White has been developed as an early-maturing breed which attains suitable proportions for killing at 100 lb. live weight for pork. The Large White, on the other hand, a larger breed, is rather later in maturing and attains suitable proportions for killing at 200 lb. live weight for bacon (figure 7).

The conditions of growth necessary for developing these two different types have been studied by MCMEEKAN [15]. He grew pigs from the same litter along predetermined growth-curves by changing the plane of nutrition at different phases of the animal's life, in a manner similar to that used by Verges for lambs (see figure 5). The optimum conditions for producing a pork pig were found to be rapid growth from birth onwards; for bacon, on the other hand, the optimum conditions are rapid growth to 16 weeks old and then slower growth by restricted rationing, so that the 200 lb. live weight is attained in about 200 days (figure 8, No. 85). By growing the animal slowly to 16 weeks old and then putting it on a high plane of nutrition to reach 200 lb. live weight in about 200 days, a lard type of pig is produced (figure 8, No. 89).

It is by keeping the animals under such conditions of management and feeding, and by selecting and breeding from those which respond best to the treatment, that the different types of pigs have been produced for the special purposes for which they are required. A typical example of the type that is now considered ideal for bacon purposes is shown in figure 9.

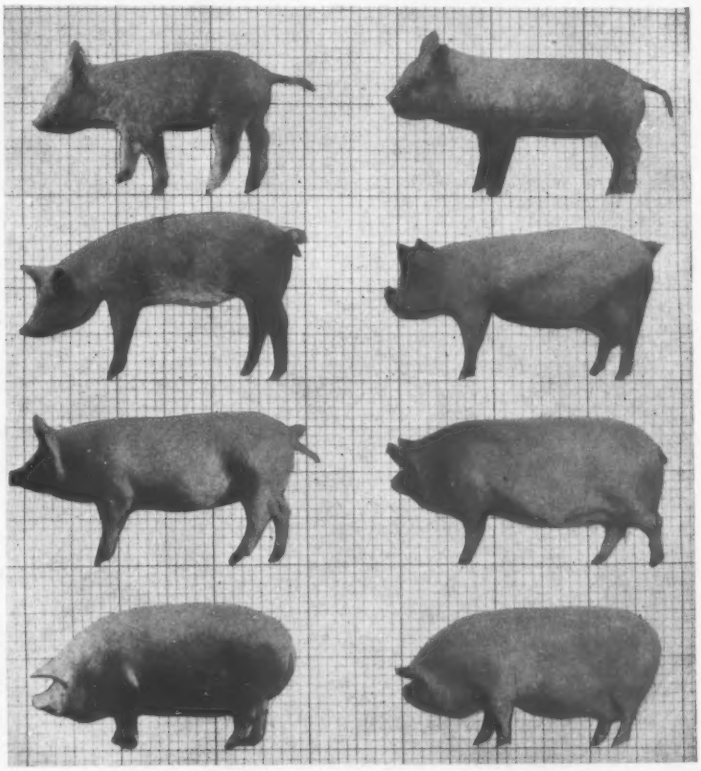
Milk and Butter-fat

Before proper selection of breeding stock can be made, it is essential that the production should be limited by the genetics of the animal and not by limitations in food supply. In order to obtain the highest production of milk of which the animal is genetically capable it is necessary that the food should be ample in amount and properly balanced so far as protein and mineral content are concerned.

The fine pastures of Great Britain ensure this during the spring months of the year by the young succulent grass with its high protein and mineral content and lack of fibre, which substance, although it fills, fails to feed the animal. As studies of milk records have shown [18], the foods fed at other times of year frequently fall below the optimum requirements for milk production. The careful compounding of suitable supplementary rations for dairy cows has therefore been the subject of much experiment and study, until at the present time these supplementary feeds can support continued milk yields of 20,000 lb. and upwards per year. Within such a nutritional environment it became an easy

FIGURE 7 – *The changes in the proportions of the pig as it grows up. In order to compare changes in proportions as distinct from changes in size all the animals have been reduced to the same height at the shoulder. The pork breeds such as the Middle White* (right) *pass through the growth-changes more quickly than the bacon breeds such as the Large White* (left), *so that while the former attain the required body proportions at* 100 *lb., the latter do not attain these proportions until they are* 200 *lb.*

Top line: 1 week old. *Third line:* 200 lb. (bacon weight).
Second line: 100 lb. (pork weight). *Bottom line:* Adult.



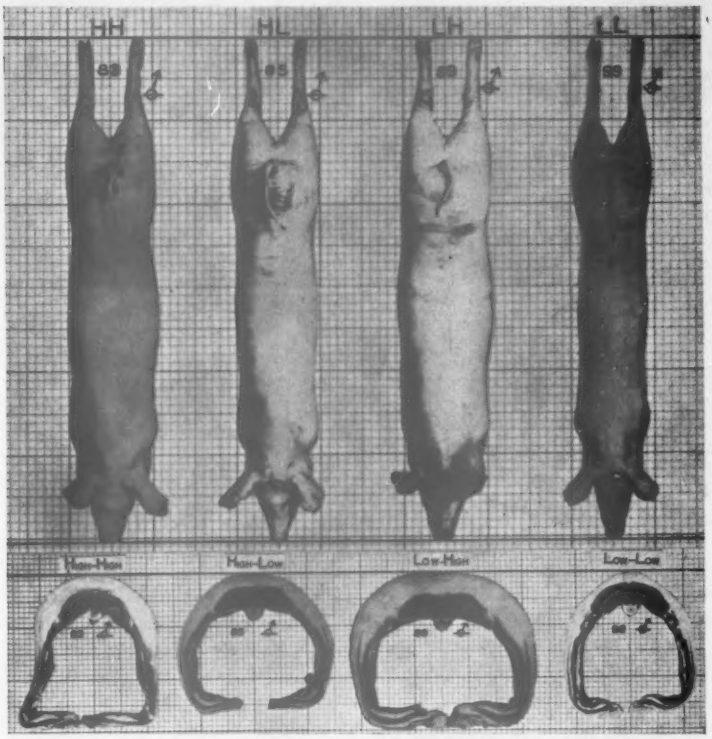


FIGURE 8 – *Carcasses and cut through the last rib of bacon pigs* (200 *lb.*) *grown along predetermined growth-curves by controlling the plane of nutrition at different stages of growth. All photographs reduced to the body and same 'eye-muscle' length.*

High-High: Quickly grown throughout. 168 days old.
High-Low: Quickly grown to 16 weeks; afterwards grown slowly. 196 days old.
Low-High: Slowly grown to 16 weeks; afterwards grown quickly. 196 days old.
Low-Low: Slowly grown throughout. 315 days old.

High-High produces the pork type, though because it has passed the right weight (100 lb.) it is now too fat. *High-Low* produces the bacon type. *Low-High* produces the lard type.

matter to select for breeding purposes cows which have a high development of udder tissue. Many other problems naturally followed this increase in udder tissue. For example, as the rate of milk secretion goes up, the pressure of milk within the udder increases and slows down further production [10]; milking therefore had to be undertaken more frequently before higher levels could be reached. Similarly, attention had to be paid to the elasticity of the skin and udder tissue for the same reason, and to the shape of the udder, so as to ensure a long period of useful production.

In addition to these methods, in breeding for butter production the making of butter from individual cows has played a part in increasing fat-globule size and in the better creaming of the milk. Moreover, the colour of the butter-fat has been improved in such breeds as the Jersey and Guernsey by supplying the necessary substances—plant pigments—for its production. Without these pigments, proper selection of breeding stock for this quality cannot be made [25]. These qualities in milk have come to be of importance commercially, now that milk is sold to the consumer in glass bottles and the cream-line and colour of the contents can be seen.

CONCLUSIONS

The principles of modern genetics have been and are being incorporated into the administrative scheme of herd-books and registers, as well as in the practice of individual breeders. These principles are used to concentrate the most desirable germ-plasm and pass it on to future generations with a high degree of certainty, as well as to eliminate undesirable characters. In addition, each relevant new discovery is utilized to create an environment optimal for the production of desired characters. By selecting within this optimal environment the breeder can raise the level of production and quality in his animals to higher levels than were formerly attainable.

FIGURE 9 – *Large White boar of ideal bacon conformation.*

REFERENCES

[1] BULL, L. *History of the Smithfield Club*, London, 1926.
[2] CALDER, A. 'The Role of In-breeding in the Development of the Clydesdale Breed of Horses,' *Proc. Roy. Soc. Edinb.*, 1927, **47**.
[3] COX, E. W. *The Evolution of the Australian Merino*, Sydney, 1936.
[4] EDWARDS, J.; WALTON, A.; SIEBENGA, F. 'On Exchange of Bull Semen between England and Holland,' *J. Agr. Sci.*, 1938, **2**.
[5] HAMMOND, J. 'Environmental Conditions and Livestock Breeding,' *Problems of Animal Husbandry (Moscow)*, 1936, (8).
[6] *Idem. Farm Animals: their Breeding, Growth, and Inheritance*, London, 1940.
[7] *Idem. Growth and the Development of Mutton Qualities in the Sheep*, Edinburgh, 1932.
[8] *Idem.* 'Report on Cattle-breeding in Jamaica and Trinidad,' *Pub.* 58, *Empire Marketing Board, London*, 1932.
[9] *Idem.* 'Judging Mutton and Lamb Carcasses for their Market Suitability,' *Rept.* 36, *Int. Conf. Nat. Sheep Breeders' Assoc.*, London, 1937.
[10] *Idem.* 'The Physiology of Milk and Butter-fat Secretion, I—Milk Pressure in the Udder,' *Vet. Rec.*, 1936, **16**, (17).
[11] HIRZEL, R. 'Factors affecting Quality in Mutton and Beef Carcasses,' *Onderstepoort J. Vet. Sci.*, 1939, **12**.
[12] *Journals, British Dairy Farmers' Association*, London.
[13] *Journals, Royal Agricultural Society*, London.
[14] KELLY, R. B. 'Zebu (Brahmin) Cross Cattle and their Possibilities in North Australia,' *C.S.I.R. (Aust.), Progress Rept. No.* 4, 1940.
[15] MCMEEKAN, C. P. 'Growth and Development in the Bacon Pig, with special reference to Carcass Quality,' *J. Agr. Sci.*, 1940, **30**.
[16] PALSSON, H. 'Meat Qualities in the Sheep, with special reference to Scottish Breeds and Crosses,' *J. Agr. Sci.*, 1939 and 1940, **29** and **30**.
[17] RHOAD, A. D. 'The Influence of Environmental Temperature on the Respiratory Rhythm of Dairy Cattle in the Tropics,' *J. Agr. Sci.*, 1936, **26**.
[18] SANDERS, H. G. 'The Variation in Milk Yields caused by Season of the Year, Service, Age, and Dry Period, and their Elimination,' *J. Agr. Sci.*, 1928, **18**.
[19] *Science in War*, Penguin Books, Harmondsworth, Middlesex, 1940, 90.
[20] TROWBRIDGE, P. F.; MOULTON, C. R.; and HAIGH, L. D. 'Effect of Limited Food Supply on the Growth of Young Beef Animals,' *Missouri Agr. Exp. Sta. Res. Bull.* 28, 1918.
[21] VERGES, J. B. 'The Effect of Nutrition on the Carcass Quality of Suffolk Cross Lambs,' *Suffolk Sheep Soc. Ybk.*, Ipswich, 1936.
[22] WALLACE, R., and WATSON, J. A. S. *Farm Livestock of Great Britain*, Edinburgh, 1923.
[23] WALTON, A. *The Technique of Artificial Insemination*, Imp. Bur. Animal Genetics, Edinburgh, 1933.
[24] *Idem* and PRAWOCHENSKY, R. 'An Experiment in Eutelegenesis,' *J. Hered.*, 1936, **27**.
[25] WHETHAM, E. O., and HAMMOND, J. 'Factors affecting Milk and Butter-fat Secretion: II—The Colour of Butter-fat,' *J. Dairy Sci.*, 1935, **6**.

A message from Russia

Welcome evidence of the interest aroused by ENDEAVOUR in Russia comes in the form of an article cabled to us by the Secretary of the Soviet Scientists' Anti-fascist Committee in Moscow. The article, which is written by PROFESSOR NIKOLAI DERZHAVIN, was unfortunately received too late for inclusion in the current issue and is moreover non-technical in character. At a time when the eyes of the world are fixed on the grim, heroic struggle of the Russian peoples against our common enemies, we must quote Professor Derzhavin's declaration that—

> Every day of the struggle . . . makes us stronger, steels our resistance, multiplies our energy, and increases our determination to bring this combat to a decisive and victorious conclusion, with the complete destruction of Hitler's army and the elimination of Hitlerism. In this we are more than ever determined, for we firmly know that ours is a righteous cause and that the insidious foe who so grossly miscalulated will be routed without fail. We know that together with us in this titanic struggle, for which history furnishes no parallel, are all the oppressed peoples of Europe and all progressive humanity, led by the great democratic powers Great Britain and the United States. The realization of this fact not only enhances our fighting power but fortifies our confidence that the Nazi ulcer on the body of Europe and its menace to all national freedom will be wiped from the face of the earth once and for all.

We are greatly honoured by the compliment implied in a cabled contribution from such an eminent source, and regret that we are unable to make more than brief reference to it. We are, however, happy to be able to announce that it has been decided to publish ENDEAVOUR in the Russian language, as a small tribute to our great Ally and a slight contribution to the future of Anglo-Russian scientific relations.

Newton and chemistry

DOUGLAS McKIE

Newton's great contributions to physics and mathematics overshadow his views on chemistry. His interest in this branch of science, however, is shown by numerous autograph manuscripts found among his papers. Dr McKie suggests that Newton attempted to discover the laws of chemical attraction, and to parallel in the microcosm of chemistry his fundamental work in the macrocosm of mechanics.

ISAAC NEWTON was born in the manor-house of Woolsthorpe-by-Colsterworth, a few miles south of Grantham, Lincolnshire, on Christmas Day, 1642. He was the posthumous child of ISAAC NEWTON and his wife, HANNAH AYSCOUGH. He was educated at the King's School, Grantham, and entered Trinity College, Cambridge, in June 1661, graduating in January 1664/5.

Sir Isaac Newton.
(From the painting by Van der Bank, by courtesy of the Royal Society.)

Interrupted in his further studies through the dispersal of the students owing to an outbreak of the plague, Newton returned to his home at Woolsthorpe. There, in enforced vacations extending from the summer of 1665 to the spring of 1666/7, he invented the differential calculus and discovered the composition of light and the law of universal gravitation. Any one of these would have meant immortal fame. Yet all three fell to Newton when he was in the twenty-third and twenty-fourth years of his age. Returning to Cambridge, he was elected a Fellow of Trinity College, took his M.A. degree, and in 1669, in his twenty-seventh year, was appointed Lucasian Professor of Mathematics in succession to his teacher, ISAAC BARROW, who wished to relinquish the Chair in order to study theology. In 1687 Newton published his *Philosophiæ Naturalis Principia Mathematica*, that sublime achievement of the human intellect.

But Newton, like many lesser men, loathed the drudgery of mathematical work, and it was to his relief that he was appointed Warden of the Mint in March 1695/6, and then Master in 1699, when the recoinage of the silver was completed. The change from Cambridge to London seems to have been much to his liking. He was elected President of the Royal Society in 1703 and re-elected at successive intervals until his death. He took an active part in the Society's meetings and conscientiously discharged the duties of his office. He died on 20th March, 1726/7, in his eighty-fifth year, hale and vigorous almost to his last days. His body lay in state in the Jerusalem Chamber in Westminster Abbey from 28th March, and on 4th April was buried in the Abbey near the entrance to the Choir.

Newton's achievements in mechanics are generally known to scientific readers. His chemical studies are less well known and often dismissed as 'alchemical.' Newton was very far from being a man of remote academic interests. He had a very practical mind; in his boyhood he made mechanical toys, clocks, and sundials; he was skilled with his hands, possessing, like so many scientists of the first rank, that priceless gift of 'handicraft'; and he habitually noted down, from his schooldays, interesting chemical 'recipes' that he met with. His interest in chemistry probably began when he was boarding at the house of the apothecary CLARK during his schooldays in Grantham.

This early interest in chemistry continued after Newton went to Cambridge. In 1669, the year in which he became Lucasian Professor, he bought chemicals, flasks, furnaces, and a *Theatrum chemicum*[1]. About this time, too, he experimented on the production of alloys suitable for use in the mirrors of the reflecting telescope that he had

[1]Newton's copy of this book, with numerous annotations in his handwriting, was offered for sale some years ago by a London bookseller.

designed. He fitted up one of his rooms in Trinity as a chemical laboratory and devoted much time to study and experiment. When his friend ASTON was leaving on a foreign tour in May 1669 and sought his advice, Newton advised him to observe, among other things, the methods of mining, smelting, and refining; to take note of any transmutations he might meet with; to try to find out whether 'at Schemnitium in Hungary ... they change iron into copper by dissolving it in a vitriolate water'; and to investigate whether the waters of certain rivers in the mining regions of Central Europe contained any gold, and whether this was recovered by means of mercury.

A stone from the King's School, Grantham, on which Newton cut his name.

(By courtesy of the Committee of the Grantham Museum.)

So Newton maintained his interest in chemistry, notably in the period when he was composing the *Principia*. Wearied with the burden of that supreme task, he seems to have turned to chemical experiments as a relaxation. HUMPHREY NEWTON, his assistant at that time, says:

> About 6 weeks at spring, and 6 at the fall, the fire in the elaboratory scarcely went out, which was well furnished with chemical materials as bodies, receivers, heads, crucibles, etc., which was made very little use of, the crucibles excepted, in which he fused his metals; he would sometimes, tho' very seldom, look into an old mouldy book which lay in his elaboratory, I think it was titled Agricola de Metallis, the transmuting of metals being his chief design, for which purpose antimony was a great ingredient.

Master Humphrey was not well informed. No one would consult AGRICOLA on the transmuting of metals; that noble old metallurgist was not fond of alchemists and dowsers and such-like. And Master Humphrey, and others who have whispered so knowingly to us after perusing his words that the great Newton himself was an alchemist, might have recalled that antimony was used in alloys for metal printing types long before Newton's day. It seems that antimony is a suspicious substance for men of reputation to touch; perhaps it still has some lingering association with JEZEBEL.

With regard to theory, Newton was a follower of the Netherlands chemist, JOHANN BAPTISTA VAN HELMONT (1577 or 1580–1644), who discovered the materiality of gases and revived the theory, first propounded by THALES OF MILETUS (*c.* 624–565 B.C.), that all substances were produced from water. BOYLE, though a great admirer of van Helmont, was sceptical about this theory, as about most things; but Boyle's corpuscular explanations of chemical phenomena deeply influenced Newton. Boyle was successfully using not, of course, our present atomic theory, but the Greek atomic theory, which saw in the various substances in Nature so many aggregates of differing numbers and arrangements of ultimate identical 'uncuttables' or atoms. In this view, all atoms were qualitatively the same; and therefore matter was transmutable. It is in this sense of transmutability that Newton was an 'alchemist,' and so also is the modern atomic physicist. But both are worlds away from the Philosophers' Stone and the Elixir of Life. As for the wide evidence we have of Newton's copying of extracts from alchemical authors, the significance of this has been over-emphasized. Boyle did likewise, and so have others. Such books were often rare. Moreover, Newton copied from other books as well. And his library contained chemical works other than those of alchemists. Alchemical books often gave valuable practical information on the properties of the metals.

Newton took his chemistry from van Helmont and Boyle. His world was a world of atoms and void, in which all substances were produced from water, a world of flux that would have delighted the soul of HERAKLEITOS. Let us consider some of its interesting detail. Newton's contemporaries and predecessors had discussed the apparent dissipation of matter from the tails of comets. Newton thought that gravity would presently attract such matter towards the planets, where it would replenish water lost in evaporation and in conversion into earth:

> . . . for as the seas are absolutely necessary to the constitution of our earth, that from them, the sun, by its heat, may exhale a sufficient quantity of vapours, which, being gathered together into

clouds, may drop down in rain, for watering of the earth, and for the production and nourishment of vegetables; or, being condensed with cold on the tops of mountains (as some philosophers with reason judge), may run down in springs and rivers; so for the conservation of the seas, and fluids of the planets, comets seem to be required, that, from their exhalations and vapours condensed, the wastes of the planetary fluids spent upon vegetation and putrefaction, and converted into dry earth, may be continually supplied and made up; for all vegetables entirely derive their growth from fluids, and afterwards, in great measure, are turned into dry earth by putrefaction; and a sort of slime is always found to settle at the bottom of putrefied fluids; and hence it is that the bulk of the solid earth is continually increased; and the fluids, if they are not supplied from without, must be in a continual decrease, and quite fail at last. I suspect, moreover, that it is chiefly from the comets that spirit comes, which is indeed the smallest but the most subtle and useful part of our air, and so much required to sustain the life of all things with us. (*Principia*, III, XLI, xxi.)

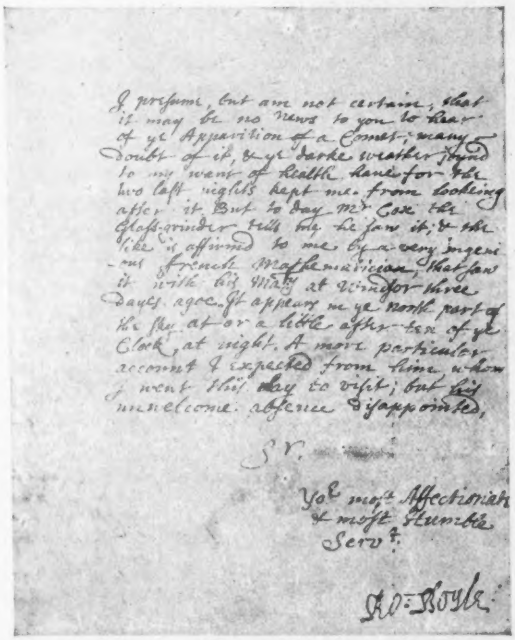
The last sentence links Newton's views with those of BOYLE, HOOKE, and MAYOW on the existence of a vital constituent in the atmosphere, isolated by PRIESTLEY long afterwards and named 'oxygen' by LAVOISIER.

In 1692 Newton drew up a paper entitled *De natura acidorum*, apparently an unfinished composition dealing with chemical affinity. It was published in 1710; but it was in the queries appended to his *Opticks* that Newton approached this problem more closely, and to these famous questions we shall now turn.

According to Newton light was material, and it seemed to him that bodies could be changed into light and light into bodies. Indeed, this appeared to him 'very conformable to the Course of Nature, which seems delighted with Transmutations.' The last clause of Newton's sentence has often been torn from its context as evidence of his being an alchemist! He reminded his readers at this point that water by repeated distillation changed into earth—a scientific 'fact' unrefuted until the work of Lavoisier, long afterwards. A sort of air may be obtained, said Newton, by heating water; and several sorts of air may be obtained when dense bodies, i.e. solids, are rarefied by 'fermentation,' a process which may be reversed so as to make the air thus produced revert by another fermentation to its first state. 'And among such various and strange Transmutations,' he asked, 'why may not Nature change Bodies into Light, and Light into Bodies?'

But chemists will always find most interest in Newton's speculations on the forces concerned in chemical change. He writes:

> Have not the small Particles of Bodies certain Powers, Virtues, or Forces, by which they act at a distance, not only upon the Rays of Light for reflecting, refracting, and inflecting them, but also upon one another for producing a great Part of the Phænomena of Nature? For it's well known, that Bodies act one upon another by the Attractions of Gravity, Magnetism, and Electricity; and these Instances shew the Tenor and Course of Nature, and make it not improbable but that there may be more attractive Powers than these. For Nature is very consonant and conformable to her self.' (*Opticks*, 4th edition, 350-1.)

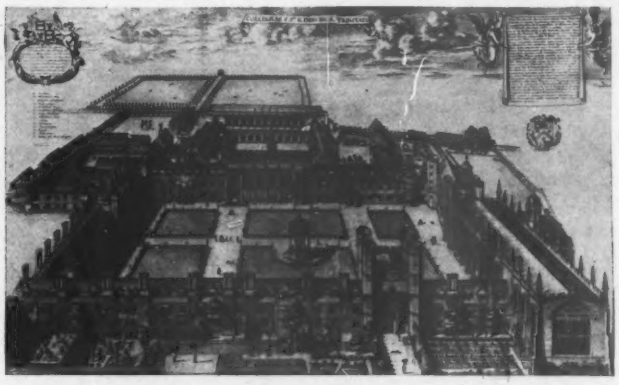


Part of a letter from Boyle to Newton about the 'Apparition of a Comet,' *a subject in which they both had a chemical interest, since each thought that the 'purpose' of comets was to make good the water lost from our planet by evaporation and by conversion into earth.*

(By courtesy of Air-Commodore Geoffrey Keynes, from a MS. in his possession.)

The deliquescence of 'salt of tartar' (potassium carbonate) Newton ascribed to an attraction between its particles and those of water vapour in the air, while salts that did not deliquesce lacked such attraction; the quantitative limit to the amount of water taken up showed that the attractive force of the salt had been 'satiated.' The development of heat on the mixing of oil of vitriol and water argued a great motion and a violent coalescence of the particles of these liquors. The action of 'spirit of vitriol' on salt and on

saltpetre, whereby the 'spirits' of these salts ('spirit of salt' and 'spirit of nitre') were produced, while the acid part of the 'spirit of vitriol' remained behind, suggested 'that the fix'd Alcaly of the Salt attracts the acid Spirit of the Vitriol more strongly than its own Spirit, and not being able to hold them both, lets go its own.' The strengths of these attractions between various substances varied, and so the vigour of chemical change ranged from slow ebullition and gentle heat to violent explosion and the heat of fire and flame.



Trinity College, Cambridge, c. 1690.

(*From David Loggan's* Cantabrigia Illustrata, *by courtesy of the Trustees of the British Museum.*)

In precipitations of acid solutions of the metals by means of alkalis, it appeared that the acid particles were attracted more strongly by the alkali than by the metal, and so they went from the metal to the alkali. A similar explanation suggests itself for the deposition of copper from an acid solution of that metal by means of iron. This last example and its explanation remind us that Newton had mentioned it to Aston in 1669 as worthy of his inquiry; what it also suggests is that it can hardly be regarded as evidence for Newton's devotion to alchemy.

It is clear that Newton was greatly interested in the problem of chemical attractions and forces. He considered that the particles of a salt in solution diffused evenly through the solvent as though they were moved from one another by a repulsive force, or, at least, that they attracted the water more strongly than one another. Yet, on evaporation of the solution, these same particles concreted in regular figures, which seemed to argue that before this concretion they were arranged in the solvent 'at equal distances in rank and file' under the action of 'some Power which at equal distances is equal, at unequal distances unequal.' He followed this to its logical conclusion of polarity in the particles:

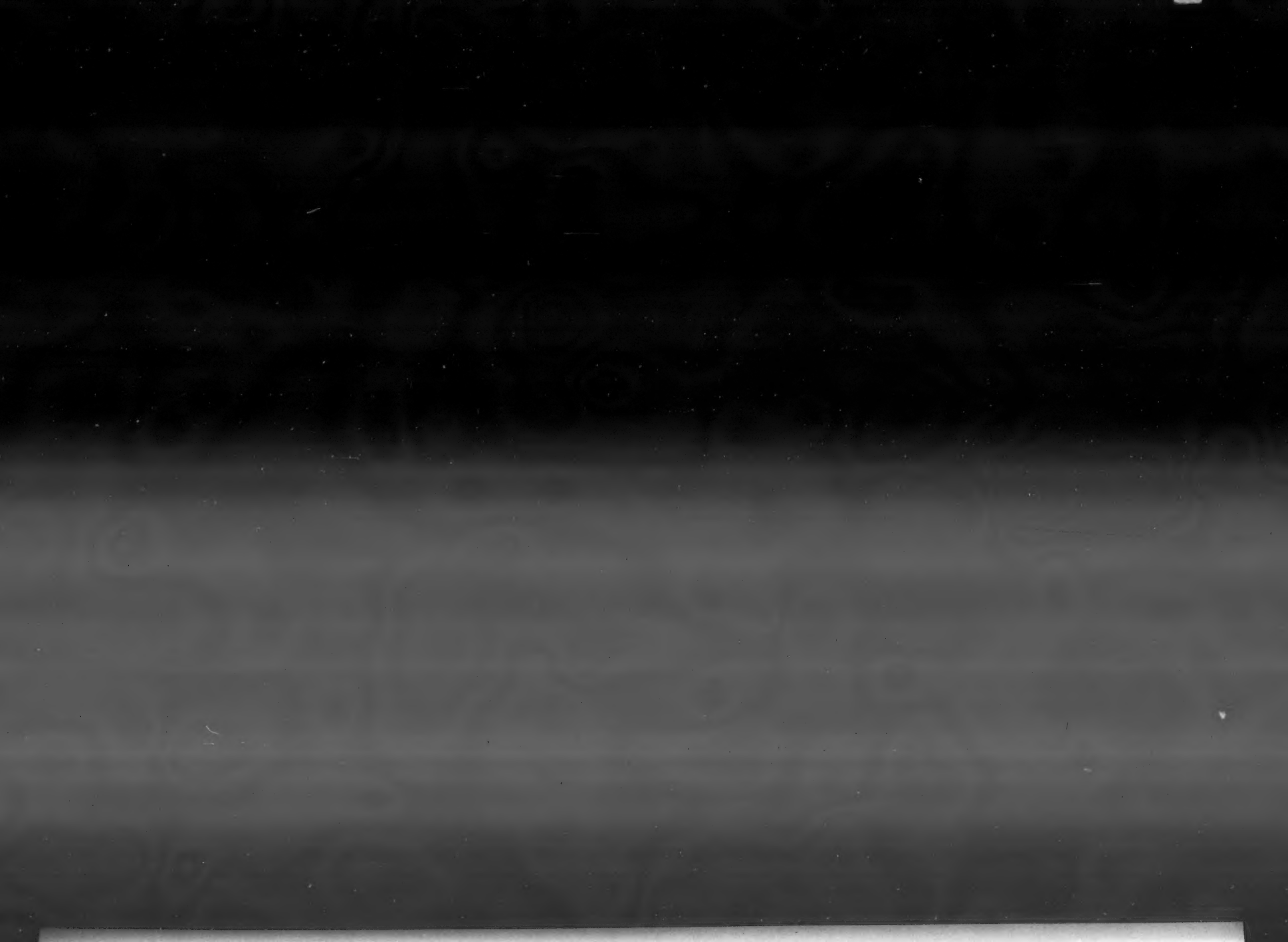
> For by such a Power they will range themselves uniformly, and without it they will float irregularly, and come together as irregularly. And since the Particles of Island-Crystal act all the same way upon the Rays of Light for causing the unusual Refraction, may it not be supposed that in the Formation of this Crystal, the Particles not only ranged themselves in rank and file for concreting in regular Figures, but also by some kind of polar Virtue turned their homogeneal Sides the same way? (*Ibid.*, 363.)

Newton was prepared to infer that the cohesion of the particles of solids was due to an attractive force, which was very strong in immediate contact, produced chemical action at short distances, and did not extend far from the particles.

Since all bodies appeared to be composed of hard impenetrable particles, some attractive force was necessary for cohesion. The concretion of particle upon particle produced larger particles with weaker powers of attraction, and so on, until the particles became of those dimensions at which chemical changes occurred and where, by further cohesion, bodies of sensible magnitude were produced. There was likewise a repulsive force, as already noted. So, said Newton:

> Nature will be very conformable to her self and very simple, performing all the great Motions of the heavenly Bodies by the Attraction of Gravity which intercedes those Bodies, and almost all the small ones of their Particles by some other attractive and repelling Powers which intercede the Particles. (*Ibid.*, 372.)

But he, who had achieved the unique triumph of formulating the mathematical law of gravitational attraction, was unable to wrest from Nature the laws of chemical attraction and to arrive at any corresponding simple numerical relationship. The problem is indeed one of far greater difficulty, since the attraction varies with the chemical nature of every reactant instead of with mere mass. Even today it would be bold to claim that progress on this problem reveals anything remarkably satisfying. Yet it might well be that here was the great object of Newton's chemical speculations and researches, and that here in the microcosm of chemistry he sought to parallel his discoveries in the macrocosm of mechanics.



Evolution of the chemical laboratory

J. R. PARTINGTON

From its nebulous beginnings in ancient alchemy, chemistry slowly assumed coherent form and at length developed into the proud science of the nineteenth and twentieth centuries. The metamorphosis in thought and theory was accompanied, and partly conditioned, by a metamorphosis in laboratory accommodation and equipment. Professor Partington acts as guide on a tour of the chemical laboratory through the ages.

The size and arrangement of a laboratory depend on the kind of apparatus it contains and the nature of the work done in it. For a long time chemical operations were of two main types, metallurgical and pharmaceutical, and the recognition of chemistry as a distinct science came later, largely as a result of the development of chemical analysis early in the seventeenth century.

We may first notice that much chemical apparatus goes back to the first few centuries A.D. The Greek treatises on the 'Divine Art' then composed in Alexandria (a centre of skilled glass-blowing) describe and depict apparatus for calcination, solution, sublimation, and distillation. The distilling flask (*lopas*) is surmounted by a spouted vessel (*ambix*), forming what was afterwards called the *alembic*. The *kerotakis* was a small charcoal brazier heating a metal plate used for sublimation. Quite small weights of materials are specified. Much of this apparatus, we are told, was devised by MARIA, fragments of whose writings were preserved by ZOSIMOS OF PANOPOLIS (third century).

The Muslim chemists, such as JABIR (eighth century) and RAZI (ninth and tenth centuries), used much the same apparatus. They also had the *athanor*, a tower furnace burning for long periods without attention and giving an equable temperature.

Alchemy came to Europe about A.D. 1200, and in the next few centuries the alchemist became familiar in literature and art; the alchemical laboratory, with its lofty and gloomy interior, forms the subject of many paintings of the Dutch School. In these, the apparatus is faithfully represented but often regrouped for artistic effect. The picture by OSTADE shows fireplace and bellows, in the foreground the alembic resting in a large pot, the crucibles, chafing-dishes, pestle and mortar, and jars.

In some such interior the alchemist pursued his elusive quest. ANDREAS LIBAVIUS (1540–1616), the author of the first textbook of chemistry, gives in 1606 drawings and plans of a 'Chemical House,' or self-contained laboratory, an ideal place whose hospitable interior was to include a main laboratory, a store-room, a room for crystallizing and freezing, a room for sand-baths and water-baths, a fuel store, and a wine cellar!

Such a goodly place was not to materialize for many a long year, and the laboratory usually consisted of one or two large rooms with stone floors to allow of the use of several furnaces built round the walls and worked by draught or bellows, which we find in place until the middle of the nineteenth century. The alembic in its later development is surmounted by a spiral condenser serving as a crude rectifying column. A laboratory of this kind in the University of Utrecht is shown by BARCHUSEN (1718). The balance is used in the same room and is here shown as hand-scales without a cover, although a balance in a glass case appears in much earlier pictures.

More commodious is the attractive laboratory shown by LEWIS (1763). Various kinds of furnaces are depicted, one surmounted by a sand-bath and alembic. A glass-blower's table with bellows is available, and in the large window-space are a barometer and two balances in glass cases. On a shelf is an early frictional electrical machine. This is the working room of a professional chemist.

In the laboratory of JOSEPH PRIESTLEY (1733–1804) we see a room adapted to experiments on gases. The fireplace and candle serve

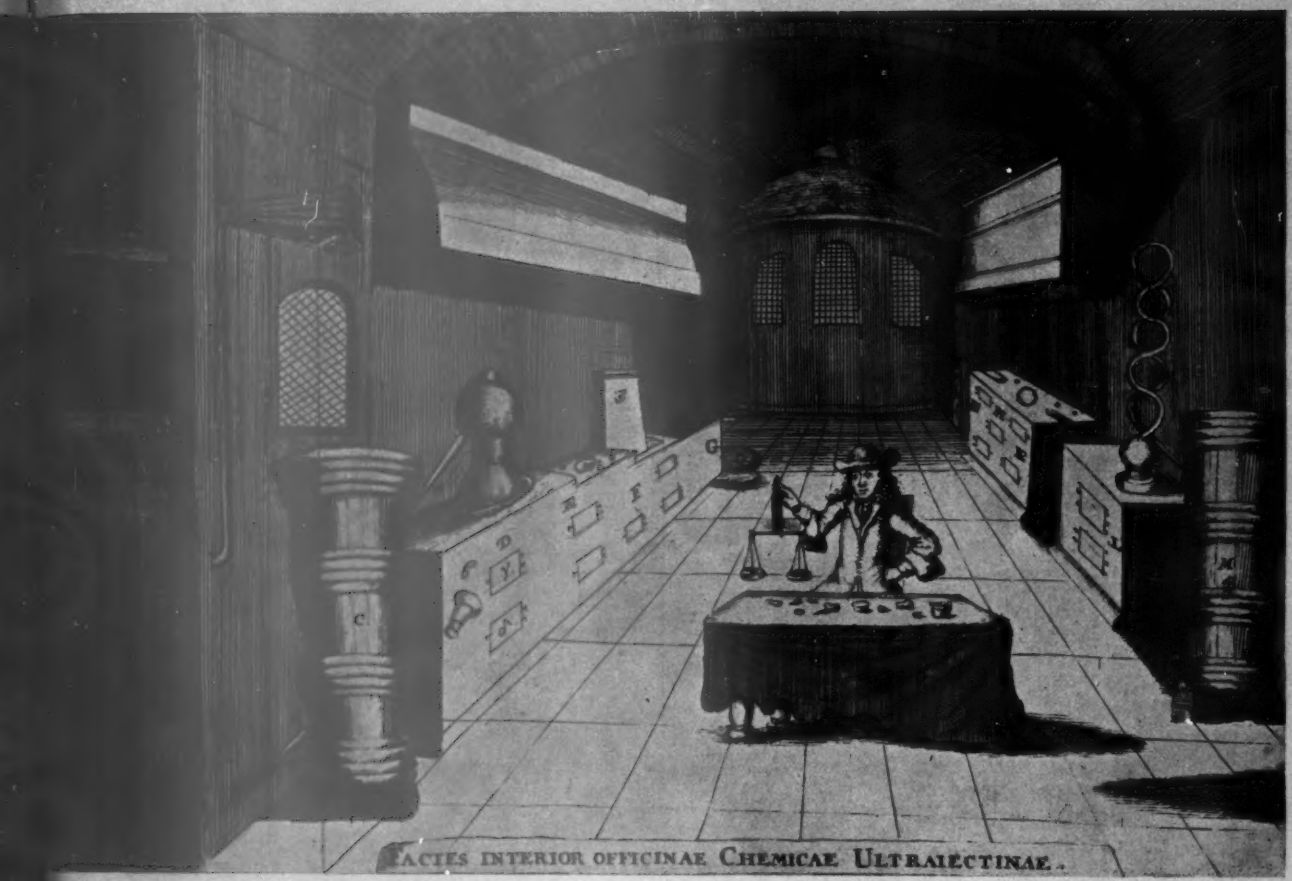
FIGURE 1 – *The Alch*
By Ostade. (National Gallery.)

FIGURE 2 – '*Chemical House.*'
From Libavius, *Commentariorum Alchymiae*, 1606.

instead of furnaces, the mercury pneumatic apparatus hangs from two large nails callously driven into the mantelpiece, and the elegant round table supports a piece of apparatus like that with which CAVENDISH was later to synthesize nitric acid from the air and obtain the first bubble of argon.

LAVOISIER (1743–94) used elaborate and costly apparatus: in a drawing by MME LAVOISIER, who is shown seated on the right, we see an experiment on respiration made shortly before his death. Two large pneumatic troughs, one filled with mercury, may be observed. Furnaces and adjuncts are missing, and much of Lavoisier's work was carried out without them. The Argand oil lamp was now coming into use and it was possible to use much smaller apparatus.

The picture of the laboratory at the Royal



URE 3 – *Chemical laboratory, University of Utrecht.* From Barchusen, *Elementa Chemiæ*, 1718.

URE 4 – *Large chemical laboratory.* From W. Lewis, *Commercium Philosophico-Technicum*, 1763.

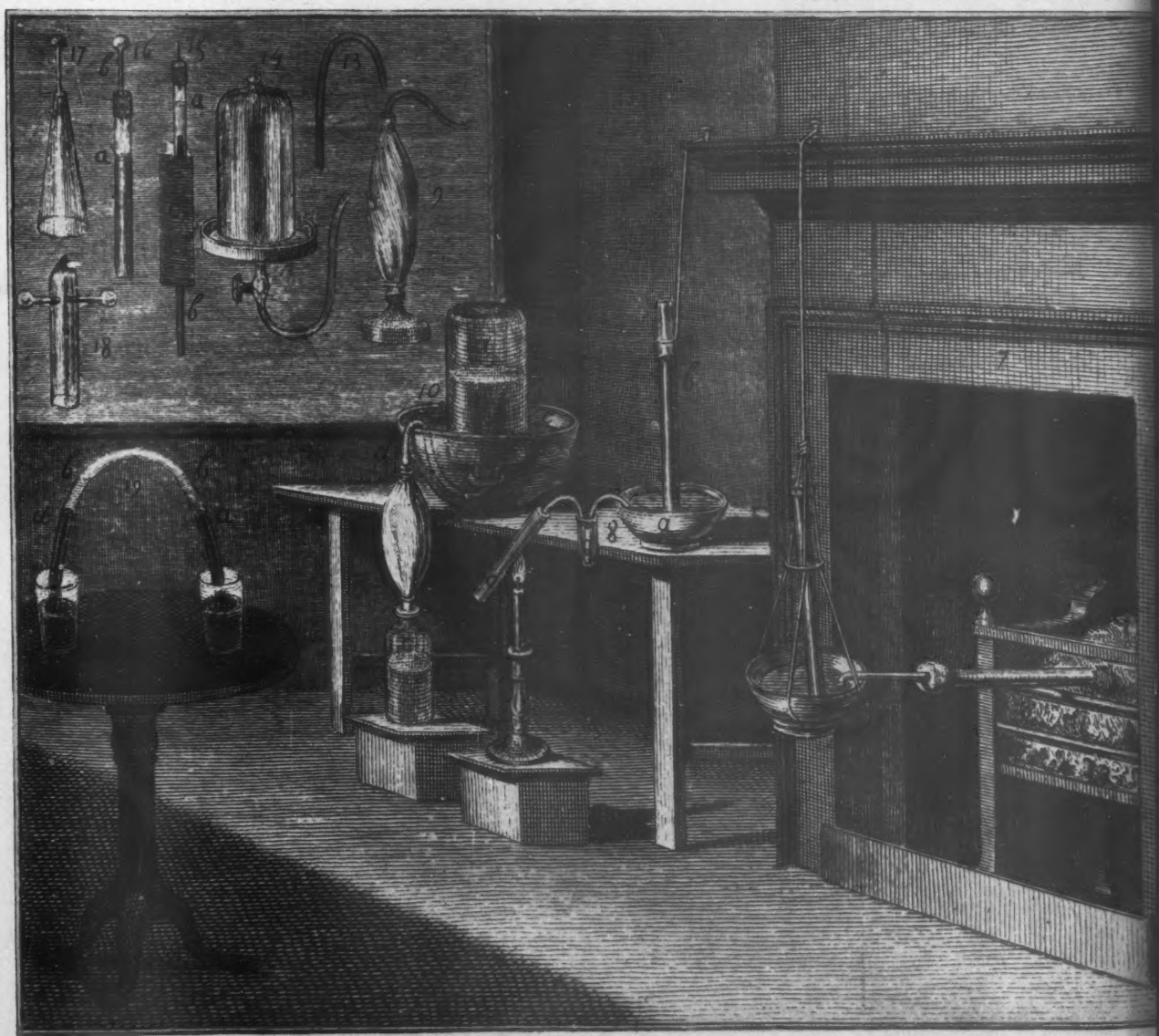
Institution about 1840 shows a large fixed furnace with a sand-bath top, the portable furnaces standing on a shelf, the bellows, and (on the left) an alembic. On the right is a cylinder frictional electrical machine. The floor need no longer be made of stone or brick, but can now be of wood.

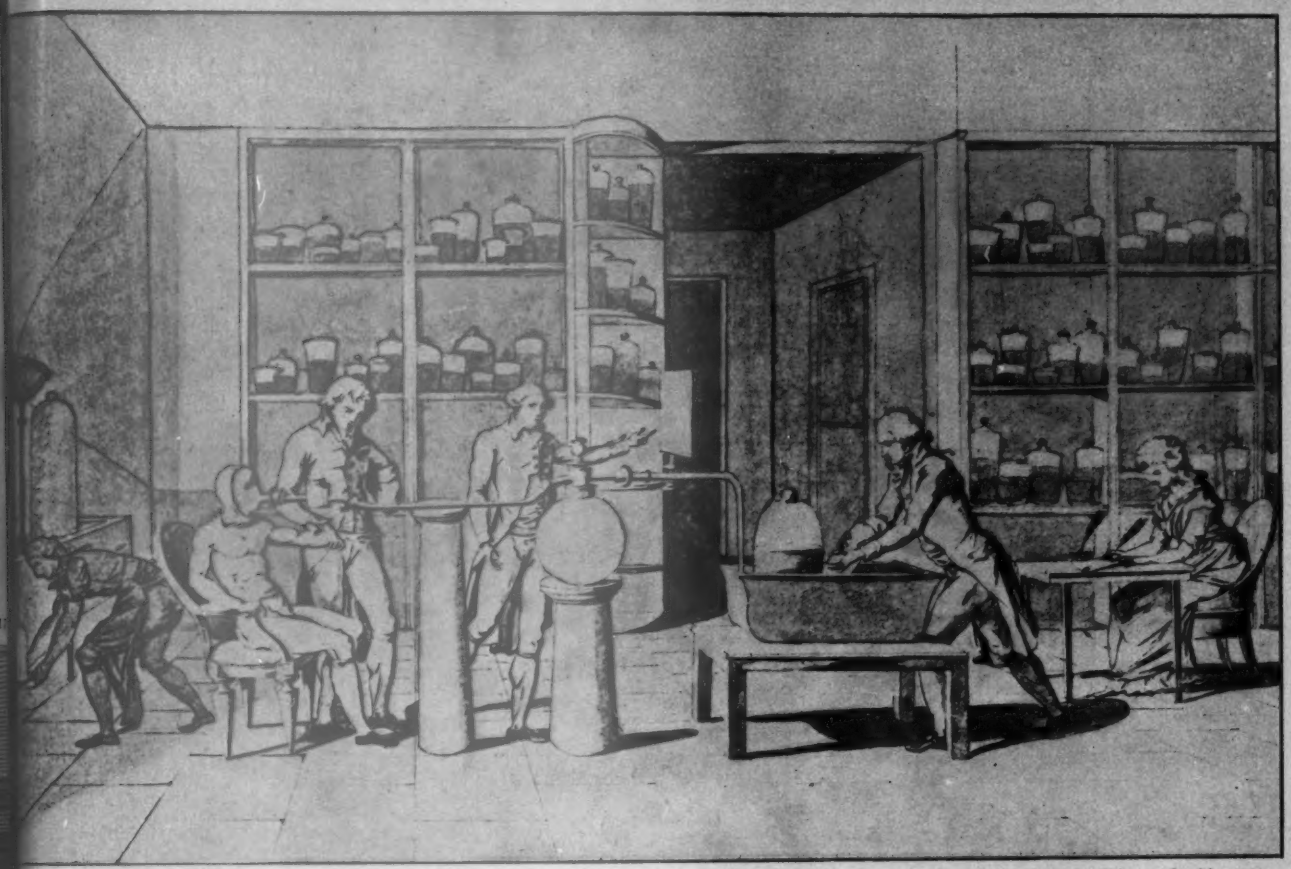
The teaching laboratory of LIEBIG at Giessen in 1842 was a place more familiar to a modern chemist than any which have gone before. Heating is still by charcoal; this was fanned and threw off a fine dust which covered everything in the laboratory. The Argand spirit lamp, used for smaller operations, is seen on the bench on the left.

By this time many laboratories used coal-gas. In 1853 the Bunsen burner appeared, and this and its near relation the ring burner still hold their place in the modern laboratory. In this the glass apparatus is still very like that of the earliest period, and an unbroken continuity of development can be traced in the laboratories here illustrated.

The twentieth century research laboratory unites complexity and convenience of resources with chaste severity of design. Water, gas, electricity, steam, and compressed air are unobtrusively but immediately available. The alchemist's untidy miscellany of phials is replaced by orderly rows of stoppered jars and bottles. Fume-cupboards obviate contamination of the atmosphere, and there is certainly no reason why chemists should resemble PARACELSUS'S ideal adept, who wore leathern dress and apron and was dirty and sooty like a smith.

FIGURE 5 – *Priestley's laboratory.* From *Experiments and Observations on Different Kinds of Air,*





URE 6 – *Lavoisier's laboratory.*

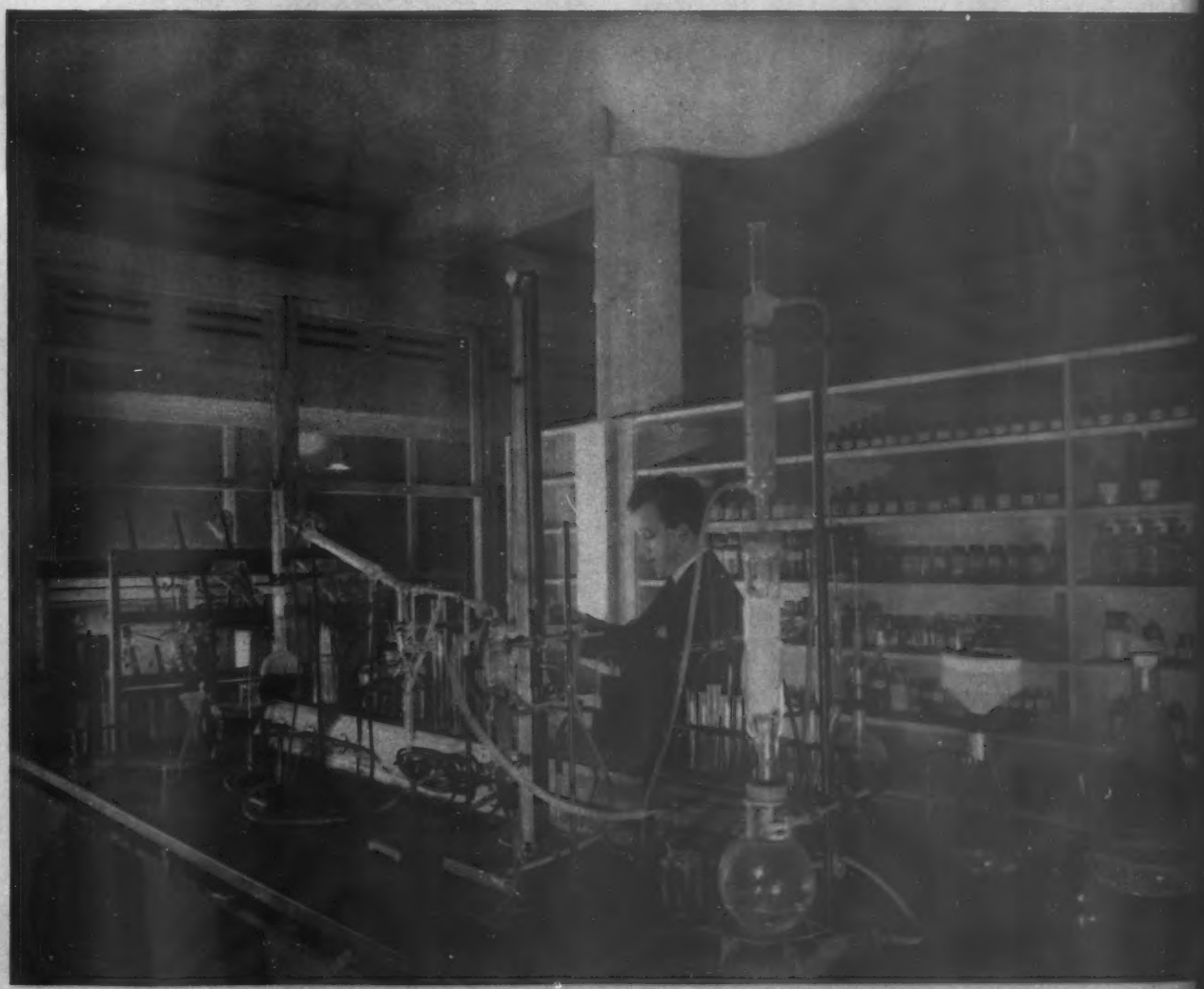
From Grimaux, *Lavoisier*, 1888.

URE 7 – *Royal Institution laboratory.*

From Bence-Jones, *Life and Letters of Faraday*, 1870.

FIGURE 8 – *Liebig's laboratory at Giessen.* From a drawing by Trautschold, 1842.

FIGURE 9 – *Typical modern research laboratory.*



The photographic plate in nuclear physics

C. F. POWELL

The structure and behaviour of atomic nuclei continually offer new problems to tax the genius of physicists. Many of these problems involve the collection and recording of large numbers of quantitative data, processes which are liable to be both laborious and lengthy. Dr Powell describes methods of detecting charged particles, of determining their energy, and of mapping their distribution after scattering, much more economical of time and material than those hitherto employed.

(1) THE PHOTOGRAPHIC PLATE AS A DETECTOR OF CHARGED PARTICLES

The development of our knowledge of atomic nuclei depends on the solution of two main technical problems: the production of fast charged particles with which to bombard the nuclei, and the development of methods for the detection of the particles arising as products of the bombardment. A modern design of what is perhaps the most important instrument for the production of bombarding particles of great energy, the cyclotron, has already been described in the pages of ENDEAVOUR (Vol. I, pp. 40 and 41). The purpose of this article is to describe briefly some of the recent developments in the application of an old method of detecting the products of nuclear disintegrations, based on the use of the half-tone photographic emulsion.

For many years it has been known that if α-particles impinge upon a suitable fine-grain photographic emulsion the tracks of the particles, after development, are represented by a linear succession of developed grains. As an example, figure 1 shows a microphotograph of the tracks produced by the α-particles from uranium. The tracks shown in figure 1 are less precise than those obtained in WILSON expansion-chamber photographs, and for many years it was considered that the uncertainties in the lengths of the tracks, i.e. in the range of the particles, was so great that the usefulness of the method was seriously restricted. Several writers, notably BLAU and WILKINS, made important applications of the method for the detection of the heavy particles, protons, etc., which are present in the cosmic rays. For modern work it is necessary, however, not merely to record a particle but also to be able to measure its energy, and the easiest way of doing this is to measure its range in a suitable medium. A well-established relation between the range and the energy of a particle then enables the initial energy to be deduced. With large uncertainties in the range there are correspondingly large uncertainties in the energy.

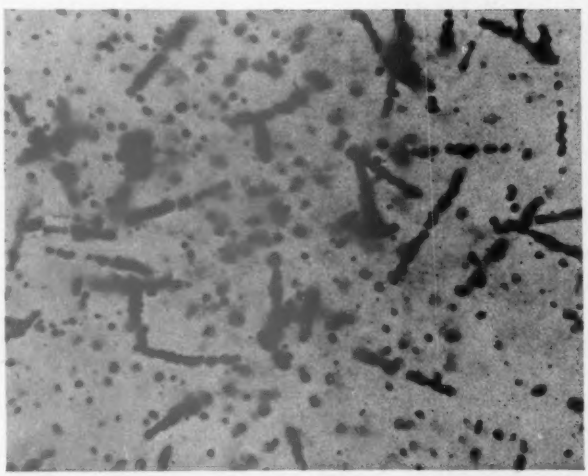


FIGURE 1 – *α-particles from uranium. There are two groups present, of mean range 2·65 and 3·2 cm. of air. Microphotograph with 3 mm., × 50 apochromatic oil-immersion objective, with × 12 eyepiece. The small depth of focus prevents more than a few grains of any track not parallel to the focal plane of the objective from being in focus at the same time. This restricted depth of focus enables the angle at which a track 'dips' into the emulsion to be determined.*

The advantages offered by the photographic method if it could be made precise were so great that it seemed worth while to re-examine it using the best available plates and good modern microscope technique. The earlier work with the method had been

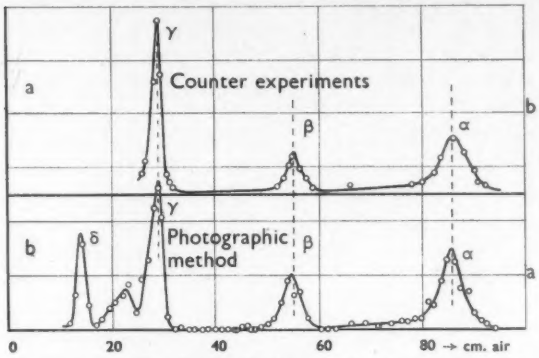


FIGURE 2 – *Range distribution of the protons from the disintegration of boron with* 600 *kv. deuterons. Curve* a *results by counter methods; curve* b *by photographic method. The proton group of greatest range corresponds to the reaction* $B^{10}_{5} + H^{2}_{1} \rightarrow B^{11}_{5} + H^{1}_{1}$, *the* B^{11}_{5} *being left in the ground state. The two groups of lower energy correspond to the* B^{11}_{5} *being left in one or other of the first two excited states.*

carried out with weak radio-active sources, so that the number of tracks per unit area of the emulsion was small and the microscopic examination of the plates very tedious. The development of artificial sources of bombarding particles of much greater intensity provided more favourable conditions for such a test. Half-tone emulsions were therefore exposed to the disintegration protons emitted when boron is bombarded by deuterons with an energy of 600 kv. from the Bristol high-tension generator. The distribution in length of the resulting tracks is shown in figure 2, where the results obtained by counter methods are reproduced for comparison. It will be seen that the results obtained with the photographic plate are not inferior to those given by the counter methods. Measurements of the ranges of the α-particles from uranium and thorium were also in satisfactory agreement with the results obtained by other methods, the two groups of α-particles from uranium of range 2·65 and 3·2 cm. (in air) being satisfactorily resolved. The reliability of the method having been demonstrated, it was applied to a number of experiments for which it appeared to be particularly well adapted, the first being the determination of the energy of fast neutrons.

(2) DETERMINATION OF THE ENERGY OF FAST NEUTRONS

Since a neutron carries no charge, it passes through matter without ionizing it and thus cannot be detected as easily as a charged particle. The most accurate method hitherto available for the determination of the energy of fast neutrons has been to pass them through an expansion-chamber filled with hydrogen. A small proportion of the neutrons passing through the chamber makes collisions with the hydrogen nuclei. If the hydrogen nucleus, i.e. the proton, is projected at an angle of less than 5° with the original direction of the neutron hitting it, it takes up more than 99 per cent. of the energy of the neutron. The proton-tracks thus produced in the gas are made visible by the expansion and are photographed in the usual manner. The impact is essentially similar to the collision of equal elastic spheres, for the neutron and proton are of almost equal mass. By measuring the range of the knocked-on protons the distribution in energy of the incident neutrons can thus be deduced.

This method has the disadvantage that it is very laborious, for thousands of photographs have to be taken if the distribution in energy of the neutrons is at all complex.

For such experiments the photographic plate method has the advantage that, unlike the expansion-chamber, with which a photograph is taken once every minute or two, the plate is continuously sensitive. It contains combined hydrogen in the gelatine of the emulsion, and neutrons passing through it thus project protons just as in the hydrogen-filled expansion-chamber. The proton-tracks are made visible by development, and by measuring the range in the gelatine of all protons projected at an angle of less than 5° with the direction of the neutron stream, the energy-distribution of the

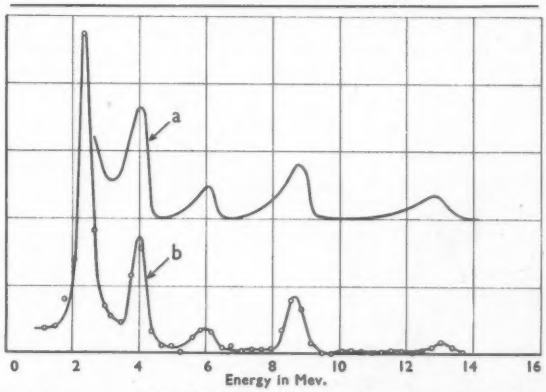


FIGURE 3 – *Distribution in energy of recoil protons projected by neutrons from the bombardment of boron by* 600 *kv. deuterons. Curve* a *by the expansion-chamber method; curve* b *by the photographic method. The neutrons are from the reaction* $B^{11}_{5} + H^{2}_{1} \rightarrow C^{12}_{6} + n^{1}_{0}$, *and the results give the energy of the first two excited states of the* C^{12}_{6} *nucleus.*

incident neutrons can be deduced just as with the expansion-chamber. With the photographic plate, however, experimental material is obtained in an exposure of some minutes which would require several months with the expansion-chamber. In experiments employing the cyclotron this economy of time during which the machine is occupied is an advantage of great importance.

Figure 3 shows the distribution in energy of the neutrons from boron under bombardment with 600 kv. deuterons, as deduced by the photographic method, the corresponding results obtained by BONNER and BRUBAKER, using the expansion-chamber, being reproduced for comparison. The measurements by the photographic method were obtained in the microscopic examination of 3 sq. cm. of an Ilford half-tone plate with an emulsion 50 μ thick. It will be seen that in this case also the resolving power attained with the photographic method is not inferior to that attained with the best alternative method available. The method has been applied to the neutrons from other of the light elements, such as deuterium, beryllium, lithium, and fluorine, under bombardment with 600 kv. deuterons, and to the same problem using the 7·4 Mev. deuteron[1] beam produced by the Liverpool cyclotron.

(3) EXCITED STATES IN NUCLEI

The experiments of the type described in the previous paragraph give us important information about the nuclei involved in the various reactions. Thus the reaction leading to the emission of protons when boron is bombarded with deuterons (*see figure* 2) is written

$$B^{10}_{5} + H^{2}_{1} \rightarrow B^{11}_{5} + H^{1}_{1}$$

Boron isotope of mass number 10 + *Deuteron* → *Boron isotope of mass number* 11 + *Proton*

The masses of the various nuclei involved in this reaction have been determined by the mass-spectrograph, and if the appropriate values are substituted it is found that the total mass on the left-hand side exceeds that on the right-hand side of the equation. By the well-known principle of the equivalence of mass and energy the disappearance of an amount of matter Δm grams must be compensated by the appearance of an mount of energy ΔE ergs where $\Delta E = c^2 \Delta m$, c being the velocity of light in centimetres per second. This kinetic energy appears in the motion of the nuclei produced. Taking into account the kinetic energy supplied by the incident deuteron, the energy—and hence the range—of the disintegration protons can be calculated. The result is in agreement with that observed for the group of protons of longest range in figure 2, and thus the disintegration experiments give a check on the masses as determined by the mass-spectograph. Alternatively, if the mass of one of the nuclei in such a reaction is unknown, it can be computed from the energy released in the reaction as determined from such disintegration experiments.

We can account for the proton groups of lower energy in figure 2 if we assume that, just as with the electronic structure of the atom, so the energy of the assembly of protons and neutrons which constitute any nucleus can have only certain discrete values. The state of lowest energy is termed the 'ground' state, and states of higher energy are described as 'excited' states. The groups of protons of lower energy in figure 2 correspond to the product boron nucleus, B^{11}_{5}, having been left in one or another of various excited states so that correspondingly less energy is available to appear in the form of motion of the product nuclei. From the observed values of the energies of the proton groups we can calculate the energies of the various excited states of B^{11}_{5}.

In a similar way the reaction giving rise to the neutron groups shown in figure 3 is written

$$B^{11}_{5} + H^{2}_{1} \rightarrow C^{12}_{6} + n^{1}_{0}$$

Boron 11 + *Deuteron* → *Carbon* 12 + *Neutron*

and the energy of the various groups of neutrons enables us to calculate the values of the energy of the excited states of C^{12}_{6}.

Experiments of this type thus lead us to the conception of excited states in nuclei, and a great deal of information on the energy of the excited states of various nuclei has now been accumulated. Such studies may be included under the general title of nuclear energetics and are of great importance; but for the development of the theory of the nucleus they must be supplemented by others of a different type.

(4) SCATTERING EXPERIMENTS WITH ELEMENTARY PARTICLES

We regard the nucleus as built up of protons and neutrons. At relatively large distances from the nucleus the field of force is an inverse square field corresponding to the positive charge on it, but, since the nuclei are stable structures, other

[1]It is convenient to measure the energy of nuclear particles not in ergs, but as a ratio to the energy that an electron acquires in falling through a difference of potential of 1 volt. This unit is the electron volt, commonly designated 1 ev. 1 Mev. = 10^6 ev.

specifically nuclear forces of a new type must come into play at short distances. It is therefore a matter of great importance to determine the character of the forces between these elementary particles—between two protons and between a neutron and a proton—when they are very close to one another. Here the scattering method remains the most valuable, and the photographic plate has been applied to the study of the scattering of fast neutrons by protons. For this purpose it is necessary to determine the distribution in angle of the protons scattered by a homogeneous group of neutrons of high energy. Such homogeneous groups are produced, as we have already seen, by the bombardment of boron by deuterons. Using the photographic method, it has been found possible to determine the spatial orientation of a track in the emulsion with an accuracy of the order of 1°, and to study the intensity of the projected protons as a function of the angle of scattering.

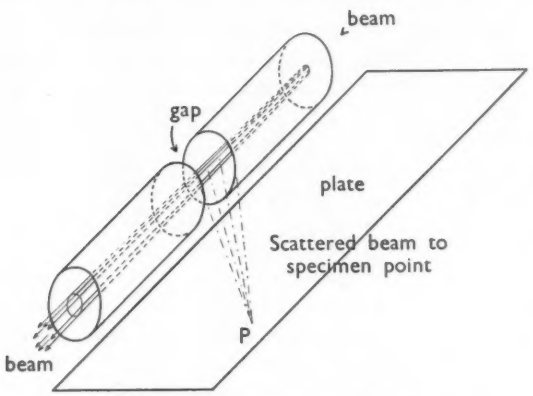


FIGURE 4 – *Schematic representation of the method for the investigation of the scattering of high-energy protons and deuterons from the cyclotron. Width of gap greatly exaggerated.*

The results of scattering experiments are most conveniently analysed by referring the observed scattered intensity to a co-ordinate system at rest with respect to the centre of mass of the colliding particles. When this is done for the observed scattering of neutrons by protons it is found that the scattering is isotropic about the centre of mass, i.e. the probability of the neutron being scattered into any small solid angle δ_ω is the same in all directions, independent of the value of the angle of scattering. This result is analogous to the scattering of light by small particles when the wave-length of the light is larger than the diameter of the particles. We are presented in this case with an aspect of the particle-wave duality of matter with which we have been made familiar in recent years by the interference effects shown by electron beams and by the development of the electron microscope. For the description of the behaviour of an electron or an atom we have to attribute wavelike characteristics to them, the wave-length λ being given by the relation $\lambda = h/mv$ where m is the mass of the particle, v its velocity and h PLANCK's constant. The isotropic scattering of neutrons by protons is then accounted for, if the range of action of the neutron-proton forces is small compared with $\lambda/2\pi$ for the interacting particles. Similar isotropic scattering has also been observed in the case of the scattering of 8 Mev. protons by protons.

(5) SCATTERING EXPERIMENTS WITH PROTONS AND DEUTERONS FROM THE CYCLOTRON

We have just seen that, with neutron sources of the energy at present available, we cannot obtain any detailed information about the neutron-proton forces. We require primary particles of higher energy and correspondingly shorter wave-length, and it should be possible to employ the higher-energy protons now available for experiments on proton-proton scattering. We can, however, as an alternative, use incident particles of the same wave-length and scatter them from larger nuclei with a more extended field of force.

For such investigations, experiments with the high-energy charged particles produced by the cyclotron are particularly important. A beam of particles from the cyclotron, of small angular spread, is defined by a system of stops. This beam is scattered by a thin foil or by the atoms of a gas, and the intensity of the scattered beam at any angle is determined. It is difficult to use the expansion-chamber for such work, and counting-methods have the disadvantage that the intensity at each angle has to be determined separately. Especially in experiments with deuterons, where the elastically scattered particles are generally accompanied by a very complex distribution of disintegration particles, a complete investigation by counting-methods would occupy the cyclotron over a very extended period. The photographic method has the great advantage that the scattered intensity at all angles can be determined from a single exposure lasting for a few minutes, and a great wealth of experimental material is thus obtained as a permanent record in the emulsion. Most of this material is normally

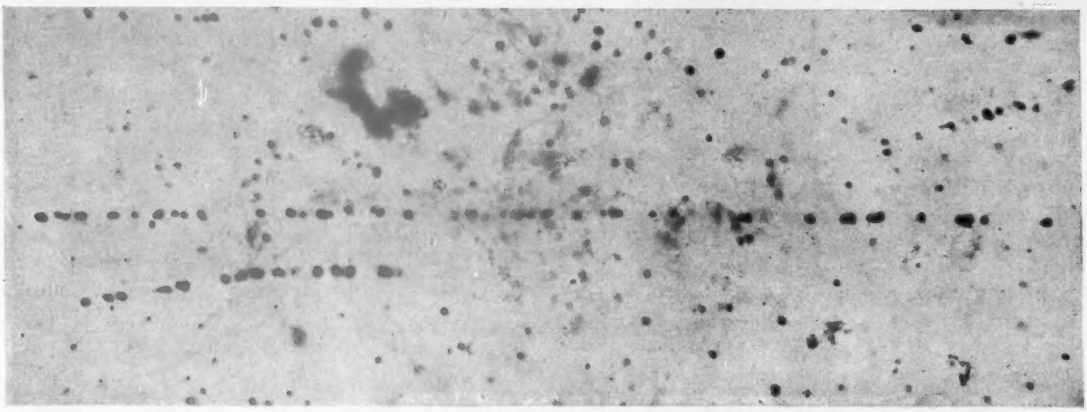


FIGURE 5 – 4·0 *Mev. protons scattered at* 30° *from neon. Microphotograph taken under same conditions as figure* 1. *The long track is an elastically scattered proton. The short one is an inelastically scattered proton, the* Ne^{20}_{10} *nucleus having been left in its first excited state at* 1·5 *Mev. in the scattering process. The tracks enter the plate at a glancing angle of about* 3°, *and in taking the photograph the plate has been tilted on the stage in order to bring the long track into focus throughout its length. Note the smaller grain density in the proton-tracks as compared with the* α-*tracks. The longest range proton so far found is a cosmic ray proton which had a range of* 14 *metres of air, roughly* 100 *times the length of the long track in the figure. The grain density of this track differs very little from that in the figure.*

not employed, but any part of the scattered distribution can be examined in detail if the preliminary measurements make it appear desirable.

Two methods of using the photographic plate in such experiments have been employed. The first, due to Wilkins, is to scatter the beam from thin foils and to record the scattered particles by a large number of separate plates; these are arranged at equal distances around the foil and are so disposed that the scattered particles make a small glancing angle at the surfaces of the emulsion. The second method, which has been developed by DR A. N. MAY and the writer in collaboration with PROFESSOR J. CHADWICK, is to make the primary beam pass down the axis of a tube provided with an interruption. The whole 'camera' is filled with the scattering gas, and particles scattered from the beam by the gas pass through the gap to enter the single photographic plate at a small glancing angle. The flat plate has its surface parallel to the axis of the primary beam and below it, and a single plate contains information on the scattering in the continuous range of angles from 10° to 170°. The essential features of the apparatus are shown in figure 4.

Using the above methods, experiments have been made on the scattering of protons by the light elements. With his camera Wilkins studied the scattering of 6·0 Mev. protons from magnesium and aluminium foils. At all angles of scattering he found two groups of protons in the scattered beam: a group corresponding to the elastic scattering of the incident protons by the nuclei of the foil, and a second group corresponding to inelastic scattering in which the incident proton excites the struck nucleus and thus leaves the collision with correspondingly reduced energy. Similar results were obtained by the second method in experiments with neon, and figure 5 shows a microphotograph of tracks scattered from this element. The long track is produced

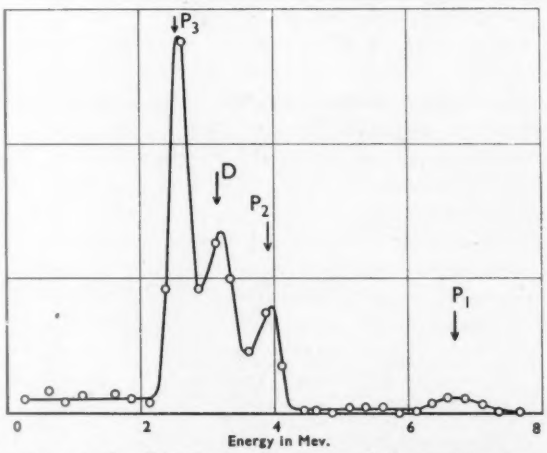


FIGURE 6 – *Distribution in energy of the particles from carbon bombarded with* 7·0 *Mev. deuterons, emitted at* 90°. *The groups marked* P_1, P_2, *etc., are protons from the reaction* $C^{12}_{6} + H^{2}_{1} \rightarrow C^{13}_{6} + H^{1}_{1}$. *The peak marked* D *is due to elastically scattered deuterons. The energy distribution is calculated from the observed distribution in range, assuming that all the particles are protons.*

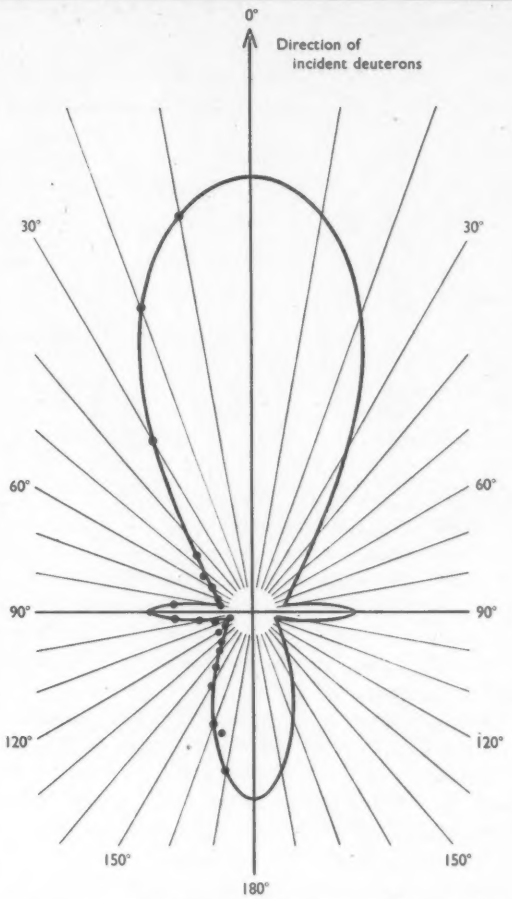


FIGURE 7 – *Distribution in angle of the intensity of the protons from the disintegration of carbon by 7·0 Mev. deuterons. Reaction* $C_6^{12} + H_1^2 \rightarrow C_6^{13} + H_1^1$, *the* C_6^{13} *nucleus being left in the ground state. The protons from the disintegration of nitrogen and oxygen by deuterons also show striking anomalies.*

by a 4 Mev. proton scattered elastically from a neon nucleus, and the short track by a proton which in the scattering process has raised a neon nucleus to its first excited state at 1·5 Mev. The distribution with angle of the intensity of the elastically scattered protons has been examined by the photographic method, using twelve different gases. The observed distributions show large departures from those to be expected if the only force between the colliding particles were the Coulomb repulsion due to the charges on the nuclei, but more striking evidence of interference effects is provided by similar experiments with deuterons.

In experiments with 7·0 Mev. deuterons the particles emitted at any angle include, in addition to the elastically scattered deuterons, protons and α-particles arising from disintegration processes. As an example, figure 6 shows the distribution of the particles emitted from carbon at an angle of 90°. For convenience in representation the distribution in range has been transformed to an energy scale on which all the particles are assumed to be protons. The weak group of particles of highest energy consists of protons from the reaction $C_6^{12} + H_1^2 \rightarrow C_6^{13} + H_1^1$, the C^{13} nucleus being left in the ground state. This group of protons is clearly resolved from the other groups at all angles, so that we are able to determine the variation of its intensity with angle over the range from 10–170°.

The result is represented in a polar diagram in figure 7, where it will be observed that the distribution shows marked anomalies, reminiscent of the variation in the intensity of the light scattered by small transparent spheres. The protons arising from the disintegration of oxygen and nitrogen by deuterons of the same energy show even more complex distributions. We are here faced with problems of considerable complexity which present nuclear theory is not yet sufficiently developed to describe, and it will be necessary to investigate the phenomena over a wide range of deuteron energies. This is a problem of the future, and physicists can still share the congratulations which LORD RUTHERFORD frequently extended to his students on the fact that in nuclear physics there are ever new worlds to conquer. It seems clear that the photographic method has a useful part to play in such investigations.

THORPE'S DICTIONARY OF APPLIED CHEMISTRY

A new edition of this invaluable dictionary is now in course of publication, but the death of SIR JOCELYN THORPE has made editorial rearrangement necessary. In order to maintain a balance between the various branches of pure and applied chemistry an editorial board has been formed, comprising PROFESSOR I. M. HEILBRON (*chairman*), DR H. J. EMELEUS, PROFESSOR H. W. MELVILLE, and PROFESSOR A. R. TODD. This board will determine the general editorial policy in conjunction with the publishers (Longmans, Green & Company Limited). DR MARTHA WHITELEY continues as editor, and DR A. J. E. WELCH becomes assistant editor.

The principal modification in the general character of the work will be an increased proportion of articles on physico-chemical subjects. The new edition, of which five volumes have already been published, is to be completed with Vol. VI, now in the press, and eight further volumes. It should be unique as a work of reference for scientific workers in the English-speaking world.

Fossils in the search for coal

A. E. TRUEMAN

Rapid and precise identification of coal seams is clearly a matter of great practical importance, especially in a country—such as Great Britain—where coal is the prime mineral resource. Professor Trueman describes how an originally amateur investigation of the fossil shells in the Coal Measures has gradually yielded invaluable criteria for the mining engineer. The results have been applied not only in Britain but in Russia and other countries.

Until a comparatively few years ago, students of applied geology were mainly concerned with mineralogy and rock structures. Palaeontology was of little importance to those engaged in the mining of ore deposits, and was generally regarded as valueless in the working of coal and bedded rocks. In recent years, the importance of the study of fossils for those seeking to apply geology to economic problems has been widely recognized, chiefly on account of the work which has been carried out in connection with oilfield development.

The use of fossils in coalfield exploration has not perhaps attracted so much attention, but the progress of this new application in Britain and some other European countries, and especially lately in Russia, has been very considerable. Since the war began, fossil-collecting has been actively carried out in practically all British coalfields as a basis for an interpretation of the structural factors involved in each area. Greater precision of information regarding the location and identification of the seams means less exploratory work needed to develop them. The value of this type of information has been abundantly proved in the mining developments in several British coalfields during recent years.

The application of palaeontology to coalfield geology is essentially nothing more than an extension of normal stratigraphical methods. Since the days of WILLIAM SMITH, who recognized that rocks of particular ages are characterized by their own peculiar suites of fossils, geologists have demonstrated that greater refinement in the study of palaeontology makes it possible to identify thinner rock groups (representing shorter time-intervals) and to correlate them over wide areas. This 'zoning' of the chief rock formations was greatly advanced during the latter portion of the nineteenth century, but the Carboniferous rocks —although the most valuable economically in Britain—shared in the progress to only a minor degree. There were several reasons for this, some of which are touched on below.

Many of the fossils which are found in the Coal Measure rocks are very familiar, and it is unnecessary to refer to the abundant trunks and roots which are frequently encountered, or to the fern-like leaves which are such striking evidence of Carboniferous vegetation: indeed, the coal seams themselves are made up of the remains of this material. In addition to the plants, there are numerous remains of the Carboniferous fauna to be met with as fossils in the rocks associated with coal seams. Apart from the comparatively rare remains of insects and land animals, and the not infrequent traces of many types of fish, there are many shells to be found in the Coal Measures. Those which are by far the most abundant in many areas may be compared in general character with the freshwater mussels (*Unio* and *Anodonta*) which occur in many rivers and ponds

Naiadites flexuosa. *Notts. coalfield.*

Naiadites flexuosa. *Notts. coalfield.*

Anthracomya warei. *Mansfield Marine Bed, Nottinghamshire.*

Associated with them are smaller bivalve shells resembling the modern *Sphaerium*, and other more *Mytilus*-like types. These Coal Measure shells are at present referred to four genera, *Carbonicola*, *Anthracomya*, *Anthraconauta* and *Naiadites*, examples of some of which are illustrated. Shells of marine types also occur in the Coal Measures, but are confined to thin beds.

The fundamental work on these shells was carried out in the last decade of the nineteenth century by an English medical man, WHEELTON HIND, who in the course of an active professional life in Staffordshire devoted his leisure to the study of fossil molluscs from the Carboniferous rocks. It may be noted that British geology owes much to the amateur investigator, pursuing the subject in his spare time, but often achieving results which place him among its leading exponents. Hind, like others who have studied the Coal Measure shells, had no connection with the mining industry and no interest in the possible economic value of his investigations: he followed his own inclinations, and his chief stimulus was a desire to know. His well-illustrated monograph, published by the Palaeontographical Society (1894–96), will long form a work of reference for European workers.

Hind confirmed the view that most of the coal-bearing rocks were deposited in fresh water. He also showed the difficulty of classifying the freshwater shells owing to their extreme variability, but demonstrated that their distribution made it possible to recognize in the Coal Measures broad zones in which certain groups were dominant. Closely associated with Hind was another Staffordshire geologist, J. T. STOBBS [1], who was more interested in mining matters and sought to show the usefulness of fossils in mining problems. He paid particular attention to the marine layers, showing that these are few in number and represent short but often widespread incursions of the sea into the freshwater lake or lagoon in which the rocks were laid down. He thus deduced that they form datum planes within the rock sequence from which the position of known seams can be measured. This conclusion, reached in North Staffordshire, has proved of the greatest reliability, and in the development of the concealed coalfield of East Nottinghamshire and Yorkshire the position of one such bed, the Mansfield Marine Bed, has been invaluable in determining the structure of the area and in tracing the chief seams sought in the deeper mining of that area (figure 1).

The use of such criteria did not extend greatly beyond these coalfields of the North Midlands of England. In some coalfields it was considered that fossils were too rare to be of use: in others, inaccurate identifications of shells led to conclusions which were contested, and generally the study of the shells made little progress for a number of years. This state of affairs led to an increased interest in the fossil plants, but at no stage was the investigation carried far enough to afford much information of value to the mining industry. The geology of the Coal Measures, not only in Britain but in most European countries, continued to lack adequate palaeontological foundation until some years later.

Renewed progress in the study of the molluscan fossils dates from less than twenty years ago, when work begun in South Wales culminated in a revived interest in the fossil faunas which has stimulated work in all British coalfields and has widely influenced research in Europe [2]. South Wales was a fortunate area for the initiation of these studies, for especially in the west, near Swansea, the Coal Measures are thick, fully developed, and fossiliferous throughout. In more northerly coalfields, when the rocks are fully represented the upper part is often almost devoid of fossils and of coal seams (as shown in figure 2), while in other areas the sequence is incomplete. It thus proved possible to divide the Coal Measures into a series of zones, each of which has now been traced, with minor modifications, into the coalfields of many countries. In their main features the same zones have been recognized as far afield as the Donetz basin.

The wide occurrence of the same types of shells in different areas, apparently at the same time, raises some interesting questions. There has long been a tendency to suppose that these freshwater types lived in lagoons more or less coincident with the present coalfield boundaries. It had been supposed that the faunas of the lagoons might show individual peculiarities, and it is therefore rather surprising to find such remarkable similarities in the succession of faunas in what were

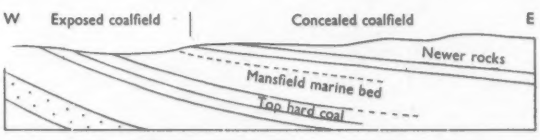


FIGURE 1 – *Diagrammatic section across the exposed coalfield of Nottinghamshire/Yorkshire and its concealed easterly extension, illustrating the use of the Mansfield Bed as a guide to the position of the underlying coals.*

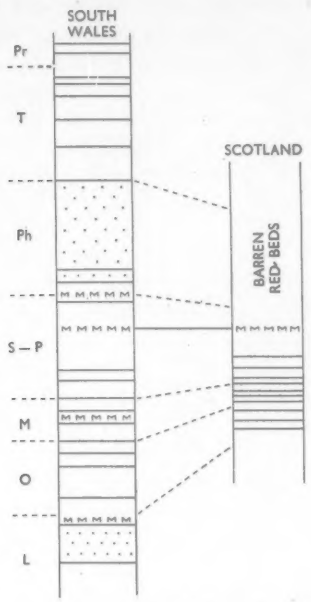


FIGURE 2 – *Diagrammatic sections (not to scale) of the Coal Measures of South Wales and Scotland. Chief coal seams indicated by horizontal lines in the sections. Letters on the left are index letters of zonal terms;* MMM *show marine bands.*

formerly regarded as different and separate basins of deposition. These similarities have multiplied to such an extent that it is becoming probable that conditions during the formation of the Coal Measures were much less local than had been supposed, and that there was, at least at certain times, comparative uniformity in freshwater areas over many thousands of square miles. Such conditions would be difficult to parallel at the present day.

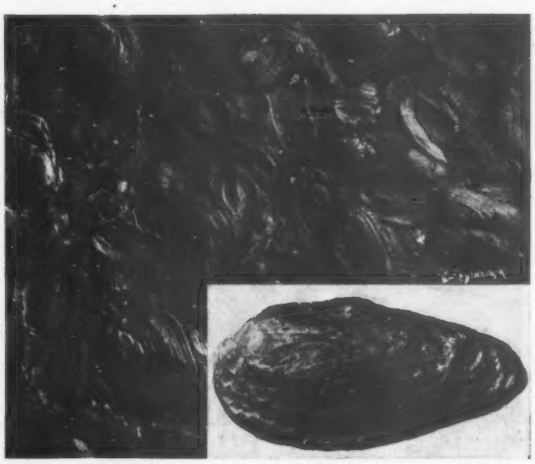
Studies of the freshwater shells have been accompanied by statistical investigations of their variants. It has been shown that many bands are characterized by a 'community' of individuals which presumably were freely interbreeding. Nomenclature here presents problems of a difficult nature, and in some cases formulae have been devised for purposes of designation, e.g. by DR D. LEITCH [3].

The use of the shells, however, depends only in part on the actual naming of individual specimens. Their application to practical problems of mining may be considered in two directions. First, the division of the Coal Measures into zones, even if some of these zones are occasionally a thousand feet thick, is of great value when unknown coalfield areas are being explored by borings. For example, where the Coal Measures may be expected to exist beneath a cover of newer rocks resting unconformably upon them, as in the concealed coalfields of Kent and of Lincolnshire, no evidence as to the probable structure of the Coal Measures may be visible in the simpler structures of the overlying rocks. Even though coal-bearing strata are found immediately beneath the latter, it may be impossible to judge whether they lie somewhere near the productive coals or whether they are in fact near the base of the Coal Measures, the productive measures having been washed away from that locality before the deposition of the newer cover. This is the point where Coal Measure zoning is of importance, for fossils collected from the borehole may be sufficient to determine the position and to indicate the probable structure of the area.

Shells are of even greater importance in the more detailed work involved in the progressive development of an area where mining is already in progress, for within small regions or individual coalfield basins the shells frequently enable the geologist to recognize much thinner rock groups. In South Wales it was found possible in the anthracite area to identify many individual seams by means of the associated faunas. This is always useful when the seams in unknown ground are being developed, but it is especially important when the seams are disturbed; in some coalfields they show great irregularity, having been faulted and folded by earth pressure since the time of their formation. Mining operations may follow a seam for some distance, to find that it is suddenly cut off; its further extension at some unknown height above or below its former level can often be determined quickly from a knowledge of the faunas occurring beyond the fault. These results are being attained in practically all the British coalfields.

Work on similar lines in many Continental countries has been developed in recent years. In some, it has been based on the work of Wheelton Hind, and has yielded results which are in general of restricted use for detailed mining problems. In Russia, its applications have been fully recognized and are there widely used in the development of the great new coalfields. The Donetz basin is in some ways the most interesting of these, and here the work of TCHERNYSHEV, among others, has revealed a remarkable sequence of shells which can be closely matched with

that in Britain [4]. The tracing of these bands has made it possible to secure rapidly an interpretation of the structural problems of the area. Subsequently, similar methods have been applied further east, for instance in the Kusnetz basin, where such workers as RAGOZIN and FEDOTOV have made detailed studies of the shells. These are only in part comparable with the fossils found in Britain and the Donetz, for the coal-bearing rocks are on the whole newer than the British Coal Measures, extending upwards, it may be supposed, from highest Carboniferous into the Permian. They therefore contain different types of shells, differing in genera from those dealt with here. But by following similar methods of rigorous collecting and careful analysis of slight differences the Russians have been enabled similarly to obtain information of great value in applied geology.



Carbonicola ornata. *Slab showing variation. Millstone Grit, Yorkshire. Inset:* Carbonicola atra. *South Wales (solid shell in ironstone).*

In the course of these studies renewed interest has been taken in the marine bands. It has been confirmed, as Stobbs and others indicated, that in the British coalfields such bands are few in number and that they occur at definite horizons. It has also been discovered that these horizons are equivalent in different coalfields. Four such bands may now be regarded as of outstanding importance, one occurring near the base of the Coal Measures, one in the midst of the productive measures in many coalfields, and two (one of them the Mansfield Bed and its equivalents) occurring above the more productive strata in most British areas. The occurrence of these bands, easily distinguished from the freshwater 'mussel bands,' is of some importance; not merely do they emphasize the uniformity of conditions in these areas during the deposition of the rocks, but they form useful and reliable guides, as easily recognized by a mining engineer as by a trained geologist, which may prevent errors in correlating the coals in a boring. Marine bands are more frequent in Russia, as they are also in parts of the U.S.A.

Meantime work on the fossil plants has also made much progress, and they too are being brought into greater use in coalfield work. Many of the common plant fossils, especially the larger and more obvious specimens, are frequently representatives of species which have a very long vertical range, extending with little change, it may be, through the greater part of the Coal Measures. Naturally such forms are of no use in the identification of seams. On the other hand, many of the ferns were more short-lived, and some, especially of rarer types, were found for only very short times: when available, these are comparable in value with the shells in the zonal division of the Coal Measures. Recognition of these plant zones on the Continent owes much to PROFESSORS BERTRAND (France), JONGMANS (Holland), and RENIER (Belgium), while in Great Britain DR E. DIX [5] has achieved notable results in this direction. A more restricted field of plant study—the separation from the coal itself of the spores and microspores, on the lines developed by DR A. RAISTRICK [6]—has yielded results calculated still further to increase our knowledge and to facilitate the search for coal.

REFERENCES

[1] STOBBS, J. T. *Quart. J. Geol. Soc.*, 1905, 495.

[2] DAVIES, J. H., and TRUEMAN, A. E. *Ibid.*, 1927, 210.
TRUEMAN, A. E. *Proc. S. Wales Inst. Eng.*, 1933, 63.
WRIGHT, W. B. *Summ. Prog. Geol. Surv. for* 1928–29, 36.
WEIR, J., and LEITCH, D. *Trans. Roy. Soc. Edinb.*, 1936, 697.

[3] LEITCH, D. *Quart. J. Geol. Soc.*, 1940, 13.

[4] TCHERNYSHEV, B. *Trans. Geol. Surv. U.S.S.R.*, 1931 (72).
DIX, E., and TRUEMAN, A. E. *Compt. rend. 2nd Cong. Strat. Carb.*, Heerlen, 1935, 1937, 185.

[5] DIX, E. *Trans. Roy. Soc. Edinb.*, 1934, 789.

[6] RAISTRICK, A., and SIMPSON, J. *Trans. Inst. Min. Eng.*, 1933, 225.
Idem. Ibid., 1934, 142.

Rediffusion: a development of broadcasting

PAUL ADORJAN

The novelty of broadcast reception has long since evaporated. Listeners now demand complete fidelity of transmission and freedom from fading and distortion. With wireless transmission this ideal is frequently unattainable. Mr Adorjan describes and explains the many advantages offered by 'rediffusion,' or wire transmission, for which he predicts a great future.

Soon after the invention of the telephone, it occurred to some far-sighted people that this invention provided an excellent means for the distribution of news, education, and entertainment. The original telephone systems, in their simplest forms, were designed and operated to interconnect two points by means of wires, addition of telephone instruments and batteries at the two ends enabling conversations to be carried on in both directions. With the introduction of the telephone exchange and organized telephone systems, telephone conversations were no longer limited to two fixed interconnected points, but any one of a large number of subscribers belonging to such a telephone system could be connected to any other subscriber on the same system. It is well known that these telephonic systems have gradually developed into urban, regional, national, and world-wide systems. Before the present war, it had become possible to talk by means of the telephone to almost every inhabited part of the world.

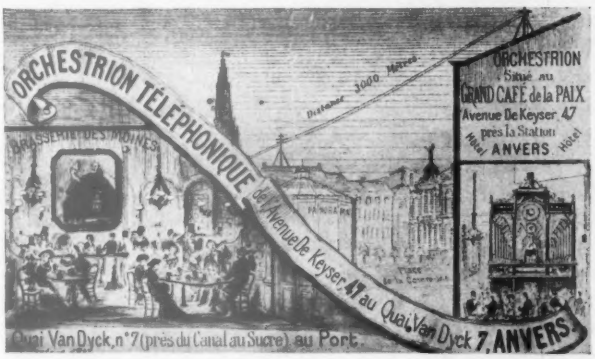

ORCHESTRION TÉLÉPHONIQUE
ORCHESTRION
Situé au
GRAND CAFÉ de la PAIX
Avenue De Keyser 47
près la Station
ANVERS
Distance 3000 Mètres
BRASSERIE DES 3 MOINES
Quai Van Dyck, n° 7 (près du Canal au Sucre) au Port.
Avenue De Keyser 47 au Quai Van Dyck 7. ANVERS

FIGURE 1

Since the eighties of the last century, following the improvements achieved in telephone technique, many attempts have been made in different countries to introduce the telephonic broadcasting of news and entertainment. In the simplest form, a microphone and battery were placed near some source of entertainment and connected by means of wires to some other place which was equipped with telephone receivers.

Thus entertainment, such as music, was made audible to listeners some distance away. A simple scheme of this kind is illustrated in figure 1, showing a print dated 1880. It will be seen that the music produced by the 'orchestrion' situated at the *Grand Café de la Paix* at Antwerp is being listened to by patrons at the *Brasserie des Moines* some two miles away. Other similar systems were erected in different parts of the world, and commercial organizations, sometimes associated with telephone companies, started to operate such systems on a revenue basis. The organizations concerned built wire systems with wire feeders radiating from a central point, and then connected individual subscribers to these communal feeders. It soon became apparent that, just as in the case of the telephone, the economics of the system largely depended on the subscriber density, i.e. the number of subscribers who were connected to the system in a given area. To make the system attractive, it was usual to connect the central distribution point to various theatres by means of private wire lines and thus make up programmes chosen from operas and plays which gave entertainment value by means of sound only. Periodically, news bulletins were read out from the central distribution point.

These systems, with some exceptions, did not prove a success, very largely owing to the fact that programme material was not specially prepared for presentation by sound only and therefore lost

much of its interest. Also the technical facilities available did not allow a very high standard of reproduction, and even operas and symphony concerts lost much of their true perspective from the listener's point of view.

It would take up too much space to describe the technical details of the early systems, but the difficulties that had to be overcome in days before the invention of the thermionic valve will be appreciated if it is mentioned that when growth in the number of subscribers necessitated transmission of more electrical power, this was usually supplied by means of additional microphones at the source.

With the development of radio transmitting and receiving equipment, radio broadcasting for entertainment and educational purposes was established in nearly all parts of the world. The number of listeners became very considerable, and the revenue derived from the licences and other forms of taxation enabled the organizations responsible for the programmes to originate really good programmes specially prepared for sound broadcasting only. It was not long before the quality of broadcasts reached such a high standard that the main object in reception became clear reproduction and the novelty interest gradually faded. Thus the listening public gradually gauged programmes by their entertainment value and reality of reproduction, rather than by the distance between the transmitter and the receiver. This, except in the case of certain special programmes, is now of very little interest.

Very soon after the introduction of radio broadcasting, it was appreciated that in some industrial areas clear wireless reception was almost impossible. Also, in spite of the many improvements made by the B.B.C. in the United Kingdom and by other equivalent broadcasting organizations abroad, nearly every country has areas where reception for at least certain parts of the day or night is unsatisfactory. With the demand for alternative programmes this problem is even more serious, as still more equipment is required to give two radio programmes throughout the country.

Increased popularity of radio broadcasting brought suggestions in England and various parts of the Continent of Europe for the distribution of broadcast programmes by wire direct to the subscriber's premises, where they were to be heard by means of headphones or loudspeakers. While some of these schemes required the use of a special network, others recommended the utilization of existing networks such as the telephone and electric mains systems.

In England various methods of distribution of broadcast programmes over wire are known by the name of 'rediffusion.' Briefly, the main groups under which rediffusion systems can be classified are as follows:

(1) *Radio Frequency Rediffusion—*
On existing networks.
On special networks.

(2) *Audio Frequency Rediffusion—*
On existing networks.
On special networks auxiliary to existing network.
On special networks.

The method adopted in England has been audio frequency distribution by special networks erected for the purpose.

While various advantages can be claimed for any of the five systems listed above, only the last has been used successfully in practice. Its success can be attributed to the simplicity of the scheme, which, while giving excellent results, can be operated satisfactorily on an economic basis. In the case of the high-frequency schemes using existing networks or special networks, it is essential to have at the subscriber's house a receiver which will select the radio frequency-signal carrying the desired programme out of two or three such programmes that may be distributed along the network. The signal received has to be converted into audio frequency-signals and amplified to a sufficient level to operate a loudspeaker. Such a receiver will have three or more valves and will require connection to electricity mains or batteries.

In the case of distribution at audio frequencies by special networks, all that the subscriber requires is a programme selector switch, a loudspeaker, and a volume control. It is usual to distribute two or three programmes, using a separate pair of wires for each programme, and the duty of the programme selector switch is to connect the loudspeaker to the line carrying the programme desired. The programmes are sent down the line at a sufficiently high level to operate permanent-magnet loudspeakers at such volume as to give adequate sound output for an ordinary room.

At the time of writing there are about 400,000 homes in Great Britain obtaining their radio programmes by means of rediffusion. This

number may seem small compared with the total of about ten million licence-holders. It must, however, be remembered that until 1939 only short-term licences were issued by the Postmaster-General to companies operating rediffusion systems, and therefore some reluctance was shown by the companies to erect new systems requiring considerable financial investment. In 1939 the Government decided to extend the licence of rediffusion companies by a further ten years, and very considerable development would have resulted had it not been for the intervention of the war, resulting in shortage of man-power and materials. In areas where rediffusion systems have been established, a large proportion of the population receives its programmes by this means. It is indeed not uncommon to find areas where one in three or even one in two houses is supplied by rediffusion.

Such programmes as are not received by direct lines between the B.B.C. studios and the rediffusion stations are received at receiving stations remote from the town, equipped with appropriately designed receivers working in co-operation with special aerial systems. These aerials sometimes spread over some hundreds of acres of ground. For example, to receive the pre-war Droitwich transmitter at Plymouth and Newcastle-upon-Tyne it was necessary to erect an aerial system half a mile long at the remote receiving station in each of these areas.

The receiving stations are attended by skilled operators whose job it is to receive the various radio programmes, working to a prearranged programme chart. They monitor the programmes and bring into operation such additional equipment as may be required from time to time. Figure 2 shows the interior of a typical remote receiving station. From the remote receiving station the programmes are sent down at audio frequencies on private wires to the rediffusion central control station. This acts as supervisory control for its particular area, which may be a small town or a fairly large area including adjoining towns, depending in each case on the particular local system.

The main function of the central control station is to distribute the programmes received from the rediffusion receiving station, and also such programmes as may be received direct from the B.B.C. studios by line, to several sub-amplifying stations placed in different parts of the area it supervises. The supervisory control apparatus provided at the central control station enables

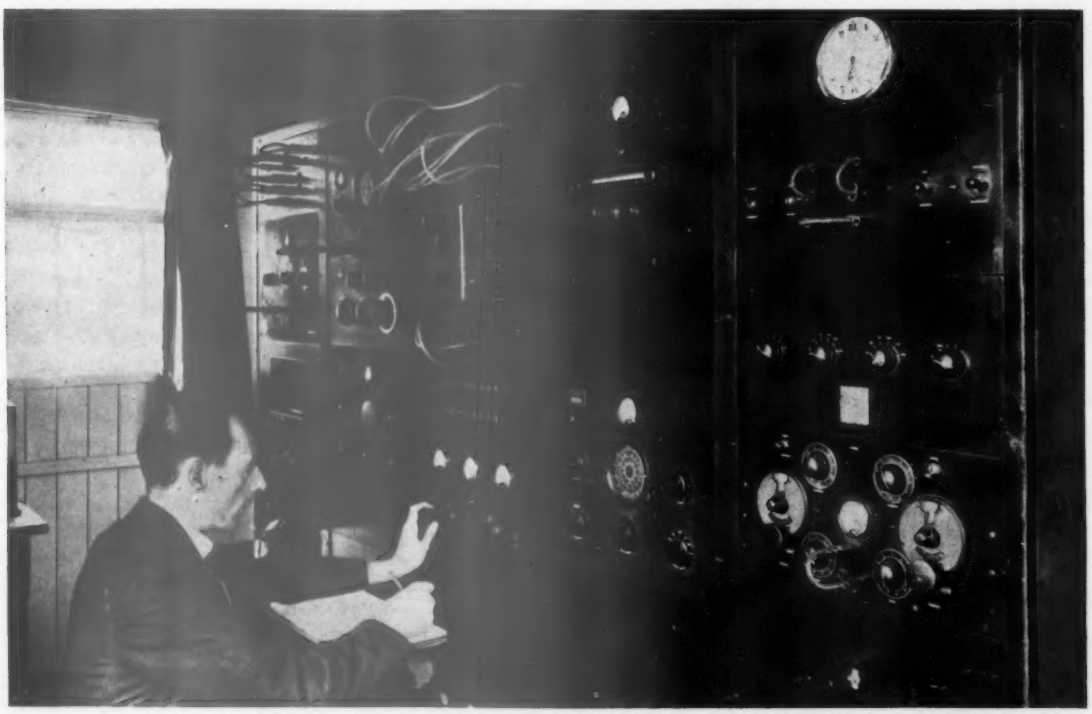


FIGURE 2

the central control operators to listen to programmes which are being amplified and sent out from the sub-amplifying stations, and to control the level of the outgoing programmes. This is to prevent subscribers from getting too low or too high a level. Any breakdowns that may occur at these unattended sub-amplifying stations are quickly noticed by the supervisory operators, and mobile service engineers can be despatched to carry out repairs where necessary. Sufficient spares are available at substations for the immediate replacement of any equipment that becomes faulty, and there are also facilities at central control for switching equipment on and off. Certain additional facilities have been installed such as are required for the relaying of air raid warnings and special messages. Various instruments are available at central control and at substations for testing the outgoing lines, and all have to be maintained in good condition. Standby

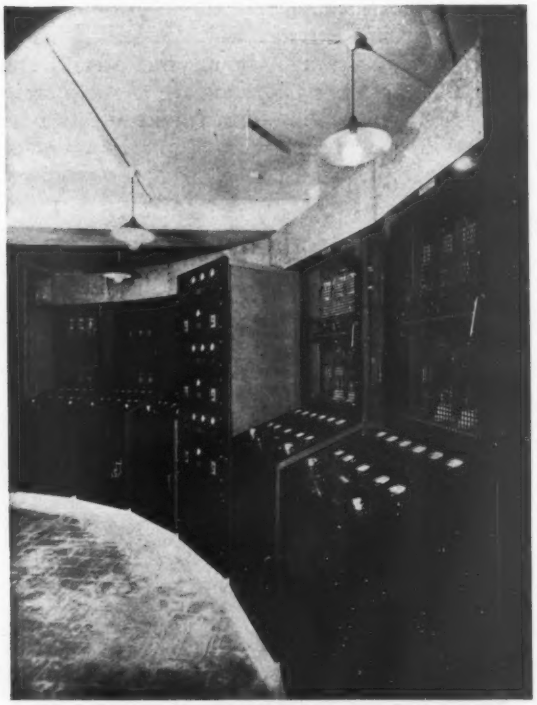


FIGURE 3

electric power generating plant is also installed at these stations.

Individual amplifiers are capable of delivering between 100 and 1,500 watts undistorted output. The size of amplifiers used at any station is decided by the maximum load connected to that station. Figure 3 shows a typical amplifying

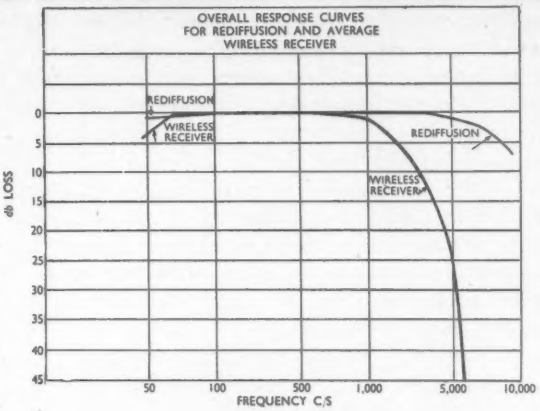


FIGURE 4

station. It is usual to distribute the programmes from the amplifying station by means of high-voltage lines to numerous transformer kiosks at which the voltage is stepped down to a lower level. The transformer kiosks are similar to the metal boxes which can be seen in streets in connection with electricity distribution, tramway control, etc. From the transformer boxes, distribution feeders radiate to the subscribers' premises.

All the distribution wires are erected and maintained by rediffusion companies. Special care is taken in this connection to design, erect, and maintain the network so that cross-talk between programmes is not audible, and that rediffusion wires shall not come into contact with Post Office or other adjoining wires. Owing to the short tenure of the licence granted by the Post Office to rediffusion companies, it has in general not been economic to install cables underground, but as far as possible rediffusion wiring systems have been made neat and unobtrusive.

In wireless reception, distortion and interference of various forms can be introduced by (1) the transmitter, (2) the medium through which the wireless waves have to travel, and (3) the wireless receiver. In rediffusion, on the other hand, by direct connection to the studio, distortion due to the transmitter is eliminated, while distortion and interference due to the intervening medium, which in the case of rediffusion is wire lines, can be made negligible in comparison with those introduced under average conditions with wireless. The third type of distortion, namely that due to the receiver, can be completely eliminated in the case of rediffusion except for such distortion as may be introduced by the loudspeaker itself.

Even in cases where direct lines are not available from the broadcasting studios to the rediffusion

stations, the directional and diversity aerials with their associated special equipment, installed at sites relatively free from interference, ensure considerable improvement on ordinary wireless reception.

The following table shows a comparison between ordinary broadcast wireless reception, a rediffusion system which receives its programmes by a wireless link at a remote receiving station, and a rediffusion system connected by direct lines to the studio:

Type and Cause of Distortion or Interference	Ordinary Wireless Reception	Rediffusion System depending on special Wireless Reception (Remote Receiving Stn.)	Rediffusion System utilizing direct wire channel from studio
Transmitter— Frequency discrimination. Harmonic distortion. Noise.	Depending on design of broadcast transmitter. Quite noticeable on some transmitters.		Not present. Additional line repeaters introduce only negligible noise and distortion.
Transmitting Medium— Fading (with or without distortion). Electrical interference. Interference from other transmitters.	Depending on local conditions. Except when near to transmitter is very bad on occasions.	Reduced to very small level by the special directional and diversity aerials and equipment used.	Not present. Line noise and distortion negligible.
Receiver— Frequency discrimination.	High notes attenuated to reduce interference.	Much less attenuation of high notes as aerial system with associated equipment gives sufficient reduction of interference.	Not present.
			Frequency discrimination introduced by rediffusion feeders small compared with radio receivers.
Second channel interference (superhets.). Valve noise. Harmonic distortion.	Usually not bad when receiver is new but gradually deteriorates.	Owing to daily maintenance by skilled engineers kept at very low level.	Not present.
Loudspeaker	Common to all systems		

While the above table gives a general qualitative view, figure 4 shows a quantitative comparison for frequency discrimination of a commercially produced wireless receiver and a complete rediffusion system, including the line amplifiers, power amplifier, interconnecting line and rediffusion network. It will be seen from this that very considerable loss of the higher frequencies occurs in broadcast receivers, while in the rediffusion system no undue loss occurs. It is appreciated that it is possible to make wireless receivers with considerably better high-frequency response than that shown in figure 4 (and such receivers are used at rediffusion remote receiving stations), but the use of receivers with improved high-frequency response is quite useless unless aerial systems requiring considerable space and a site free from interference can be utilized. If such an aerial system is not available, considerable interference can be expected even on a high-quality receiver. Figure 5 shows the overall response curve of a special receiver such as is used at rediffusion remote receiving stations. As regards harmonic distortion, by frequent measuring tests it is possible to keep rediffusion equipment in such condition as to limit the total voltage harmonics introduced to 5 per cent., which is generally accepted as a suitable upper limit. In the case of broadcast receivers also, this figure can be attained; but in practice it is found that distortion usually increases with the ageing of valves, and unless frequent checks are made and valves that have aged are replaced, such a distortion limit cannot be maintained.

One of the great advantages of rediffusion as compared with wireless reception is the almost complete absence of interference and background noise on rediffusion; and while a signal-noise ratio of 20 decibels is considered acceptable for wireless reception, in most industrial areas a signal-noise

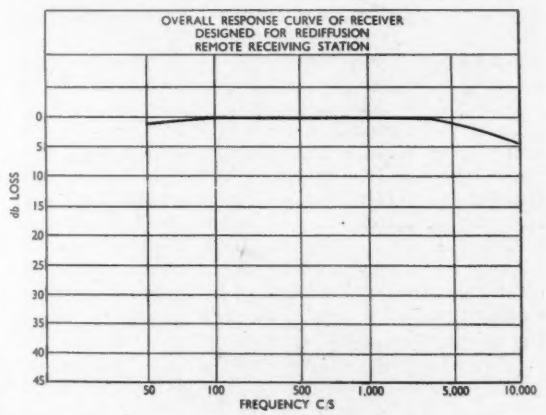


FIGURE 5

ratio of the order of 40–55 decibels is achieved by rediffusion systems without sacrifice of high-frequency response.

In view of the great advantages of wire over wireless, particularly for the distribution of broadcast programmes in densely populated areas, there can be little doubt that this method will be employed in an increasing proportion of homes. There is, moreover, no technical reason why it should not be used in future for distribution of broadcast programmes in rural areas.

Book reviews

BIOLOGY, CHEMISTRY, AND LIGHT

Living Light, *by E. Newton Harvey. Pp. xv + 328. Oxford University Press, London.* 1941. 24*s. net.*

The Chemical Aspects of Light, *by E. J. Bowen. Pp. vi + 191. Oxford University Press, London.* 1942. 12*s.* 6*d. net.*

Little excuse is needed for associating these three topics. The Biblical account of the Creation opens with the noble first fiat 'Let there be light,' and modern science has explored some but not all of the intricate ways in which the existence of living creatures depends upon the light which falls upon this planet. Light is one of the first sensations we experience when we enter the world as individuals, and from infancy to old age we rely on photochemical changes in the visual purple of the eye for most of the information we gather concerning the universe around us. The two volumes under review may be regarded as a modern commentary on this theme. They supplement one another to a considerable extent since DR HARVEY deals mainly with the emission of light by living creatures, whilst MR BOWEN outlines the picture which modern theory presents of the nature of light and of its interaction with both dead and living matter.

Dr Harvey's book is unusual and attractive. It contains an account of the biology, chemistry, and physics of the production of light by living creatures ranging in complexity from bacteria to fishes. It is written with scientific accuracy, it is fully documented, and the exposition is aided by a large number of careful drawings and photographs. Yet it is a book for the layman as well as the scientist, since it is written in a style which is as effective as entertaining. Some of the happier phrases which enliven the more severe parts of the volume may be quoted: 'Luminous organs have often been mistaken for eyes. The reason is obvious: they are eyes in reverse. Chemical production of light is the converse of the chemical detection of light.' Later in the same chapter comes: 'The smallest lamps in the world, luminous bacteria. . . .'

The opening chapter is largely historical and contains a curious quotation from BOYLE on the cause of luminosity of the sea. Then follow a critical survey and description of the organisms in which luminosity has been observed. Bacteria, jelly-fish, glow-worms, fireflies, and a wealth of strange creatures from the deeper seas are passed in review. A limitation in their distribution in Nature is noted: practically all of them are marine or terrestrial *animals*. Of plants, only bacteria and fungi exhibit luminosity, and the only freshwater organisms which are luminous are bacteria and an aquatic glow-worm.

The firefly and the glow-worm have inspired many poets, but two humbler and less well-known creatures have been most useful in elucidating some steps in the chemistry of light emission The rock clam, *Pholas dactylus*, was studied by DUBOIS who, sixty years ago, demonstrated the presence in its light-producing organs of a heat-labile enzyme, luciferase. This acts on a more stable substance, luciferin, with the emission of light. The small crustacean *Cypridina hilgendorfii*, only an eighth of an inch in length, is caught by Japanese fishermen using a fish-head as bait. If rapidly dried it can be kept for years and will still luminesce when moistened. From dried *Cypridina* a luciferin and a luciferase have been prepared by HARVEY, and later in purer condition by ANDERSON. These preparations are remarkably active, the luciferin giving a detectable emission of light at a dilution of the order of 1 in 10^{11} when *Cypridina* luciferase is added. Luciferin is not a protein; it is thought by Anderson to be a polyhydroxybenzene derivative of relatively low molecular weight.

Many other interesting topics discussed in this volume must be passed over—three may be briefly mentioned. The chapter on physiology contains an interesting discussion of the reflex mechanism of the flashing of fireflies. In a later chapter the overall efficiency of a luminous bacterium as a light-producer is computed to be 0·16 per cent. 'This tells us what percentage appears as light of all the energy required to run a bacterium.' The last chapter includes a review of the work on mitogenetic rays which are supposed to stimulate cell-division. There is a shrewd summing up: 'Indeed, the whole story is so fantastic, the findings of the investigators are so contradictory, . . . and statements of the properties of mitogenetic radiation are so at variance with what is known of the nature of ultra-violet light that it is impossible to make logic out of the reports.'

Mr Bowen's volume is rather stronger meat, but it well repays a close study. It is an attempt to present the concepts used in the theory of light and its interaction with matter without using a formal mathematical treatment. The main stress is laid on the ideas which form the basis of physical theory and the subject is developed systematically, starting with an account of the properties of light. Next comes a discussion of emission and absorption by atoms and molecules, which introduces the quantum theory and the theory of spectra. This is followed by an account of modern views on the transformation of absorbed radiation, i.e. of fluorescence and luminescence. The remainder of the book is concerned with more detailed applications of the general theory to photochemistry, photosynthesis in plants, the theory of the photographic plate and so on.

Two features of the treatment call for special mention. Mr Bowen throughout keeps his feet firmly on the ground of objective facts and refuses to be carried aloft by semi-philosophical interpretations of mathematical theories. After some of the claims which have been made for the application of quantum theory to chemical problems it is refreshing to find such statements as the following: 'Wave mechanics, while providing a unified interpretation of quantum phenomena in atoms, quantitatively correct for very simple systems, is held up by mathematical difficulties from further extensive advance of a numerical kind.'

The other notable feature of the book is the stress which is laid on experiment. The discussions are illustrated by a wealth of accurate numerical data, while valuable practical information about light sources, filters, the preparation of phosphors, etc., is contained in the text and the appendices.

S. SUGDEN

ORGANIC FORM

On Growth and Form, *by Sir D'Arcy Wentworth Thompson. Pp. vi + 1116, with 2 plates and 554 figures. University Press, Cambridge. New and revised edition,* 1942. 50*s. net.*

Since its first issue in 1916 this book has grown, by intussusception, from 793 to 1116 pages; but the form is

still the same. New work is used as further variation on a theme composed a quarter of a century ago. The incorporation is skilful, and only reference to the dates quoted enables the reader to detect the joins.

JULIAN HUXLEY on growth ratios, BERNAL on protein molecules, RIDEAL on monolayers, and many others make their appearance; but *Growth and Form* need not be read for its account of recent advances. It is a biological classic because of its unique assimilation of earlier work. Though the classical foundations are the author's peculiar domain, it is, perhaps, his draft on the speculation and experiment of later centuries which is most valuable. Biologists who have of necessity spent much time on the most recent work, to the neglect of that published before 1850, will find their perspective corrected by an occasional evening with a chapter of this book. They will make contact with a ripe and cultured mind and they may be surprised by both the depth and the liveliness of earlier thought on a great variety of biological topics.

SIR D'ARCY THOMPSON moves easily through the fields of classics, mathematics, and biology. If his lucidity sometimes makes things appear easier than they are, it is a quality of style not shared by many. His attitude is expressed in a sentence of the Epilogue: 'I know that in the study of material things, number, order, and position are the threefold clues to exact knowledge.' We welcome a modern edition of this great work and congratulate the author on the completion of a heavy task.

MACGREGOR SKENE

ANALYSIS OF THE ELEMENTS

Mass Spectra and Isotopes, *by F. W. Aston. Pp. xii* + 276, *with* 12 *plates and* 48 *figures. Edward Arnold & Company, London. Second edition*, 1942. 22*s.* 6*d. net.*

'All the elements have now been analysed' isotopically, says the author in his preface to the second edition of this book, 'and my main concern . . . is to tell how this has been done.' We may appreciate the quiet but intense satisfaction that went to the penning of these lines, for they imply the completion of an arduous and intricate task of which the main burden has fallen upon DR ASTON himself. As Englishmen, we may feel an equal, if vicarious, satisfaction that in an investigation of such fundamental importance this country has played a leading part. The first edition of Dr Aston's book is familiar to all physicists and all chemists in all parts of the world. The present edition will also achieve ubiquity, since it is indispensable. It contains a completely new chapter on modern mass spectrographs, including the double focusing types of DEMPSTER, BAINBRIDGE and JORDAN, and MATTAUCH, and Jordan's high dispersion instrument, which has a resolving power of 30,000. The third part of the book, which deals with nuclear chemistry, includes the whole of the evidence upon which the first International Table of Stable Isotopes was drawn up in 1936, together with an account of later work. The text throughout has been revised and brought up to date, and a comparison of the two editions reveals the astonishing progress made during the last decade.

A TEXTBOOK OF ATOMIC PHYSICS

Introduction to Atomic Physics, *by S. Tolansky. Pp. x* + 343. *Longmans, Green & Company, London.* 1942. 15*s. net.*

There was—and is—a real need for a book about this size and scope, treating atomic physics from the modern viewpoint. Dr Tolansky's book is written for second and third year university degree students who have not begun to specialize. There is no fault to be found with his selection and arrangement of material; in fact, Dr Tolansky is to be congratulated on having so satisfactorily solved this problem, which is of special importance in the presentation of a rapidly developing subject. This intensifies the reviewer's disappointment in finding that a work so well planned should be marred by so many faults in execution that it cannot be recommended to students.

There are many errors in the diagrams and the text. Many of them are trivial, and many would be detected at once by any fairly good student. There are, however, some which are particularly objectionable, inasmuch as they are of a kind to perplex the only type of student worth considering — the one who wishes to understand and to apply, and not merely to reproduce in examinations, what is put before him. A bad example of this is the statement that the numerical prefix in a number of named spectral terms, such as the sodium *1s* term, represents the associated total quantum number. A student who is pursuing the subject intelligently may suffer a great deal of bewilderment before he finds out that the statement is simply not true. A very similar criticism applies to a singularly infelicitous pseudo-derivation of the CHILD-LANGMUIR relation (pp. 100–102), which can only confuse any reader who is given to respecting the authority of the printed page.

It is probable that the book will sell, and that Dr Tolansky will have an early opportunity of preparing a second edition. If he is prepared to revise the text critically and very drastically, he may make a book which will be of real use to students —and this could be done without any large alteration in the general plan of the work. H. R. ROBINSON

CHROMOSOME TECHNIQUE

The Handling of Chromosomes, *by C. D. Darlington and L. F. La Cour. Pp.* 165. *George Allen and Unwin Limited, London.* 1942. 8*s.* 6*d. net.*

The study of chromosomes, in spite of the great importance attached to them, was pursued until recently only by a small group of experts, who made numerous valuable and fundamental theoretical advances with far-reaching and often unexpected implications. We know now how life in its three main aspects—reproduction, development, and heredity—is controlled by the chromosomes. Improvements in technique underlie the rapid progress, and by making the technique of chromosome-handling in its varied ramifications available to scientists, the authors of this well-produced and lavishly illustrated book have done a great service and have given an impetus to further research. Many will welcome the book and profit by it. It will certainly help to rectify the profound errors which, the authors claim, have kept many investigations, e.g. X-ray work on human cancer, outside the boundaries of objective science. It is furthermore obvious that if we are ever to succeed in unravelling and in understanding the complexities of chromosome structure and behaviour, and in controlling the main processes of life, a close integration of cytology, chemistry, and physics is not only desirable but necessary. The scientific value of this book lies in its important contribution to this goal. P. C. KOLLER

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Is Physiologist of the Animal Nutrition Institute in the University of Cambridge and a Fellow of Downing College. Born in 1889, he is the son of a Norfolk farmer and grandson of one of the foundation members of the Red Poll Cattle Herd-book. After taking a degree in Natural Sciences at Cambridge, he studied agriculture under Professor T. B. Wood and later specialized in the physiology of farm animals. He has applied modern scientific knowledge to such problems of animal husbandry as breeding, fertility, growth, and meat production, and has published numerous papers and books on these subjects. A member of many learned societies, both British and foreign, he was Guest Professor of Animal Production and Physiology at Iowa State College, Ames, Iowa, U.S.A., in 1932. He has travelled widely in order to study at first hand conditions of animal production in many different countries. Investigated problems of cattle-breeding in the tropics (West Indies) for the Empire Marketing Board, and has seen something of the same problems in Fiji, Ceylon, and Brazil. At the request of the New Zealand and Australian Councils of Scientific and Industrial Research visited these countries to survey their animal industries. Went to the Argentine to see the methods of beef and lamb production and to advise the Argentine Corporation of Meat Producers on scientific methods. His scheme for judging the suitability of Argentine lamb carcasses for the British market proved so successful that it was also adopted by Uruguay, while Australia, New Zealand, the British Dairy Show, and the National Pig Breeders' Association employ the methods he suggested for judging pork and bacon carcasses.

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Was born in Monmouthshire in 1896, though he is a Scotsman by race. After some years in the Regular Army, he entered University College, London, in 1920 and carried out research under Professor W. E. Garner on the heats of adsorption of gases by charcoal. Later he turned from physical chemistry to the history of chemistry, and is now Lecturer in the Department of the History of Science in the University of London. He has written many papers on the history of chemistry, and in 1935 published an authoritative biography of Lavoisier. His *Discovery of Specific and Latent Heats* (in collaboration with N. Heathcote) established the priority of Joseph Black's work in this field. He is one of the founders and editors of *Annals of Science*, a quarterly journal dealing with the history of science in the modern period.

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Born in 1886 in Bolton, Lancashire, he is a North Countryman of English as well as Scottish origins, and claims to combine many of the characteristics of each. He graduated at Manchester University, where he studied under H. B. Dixon, and later carried out post-graduate work in physical chemistry and thermodynamics in the University of Berlin under Nernst and Planck. He returned to Manchester as a member of the staff of the University Chemical Department, and from 1914 to 1919 served in the Army and the Ministry of Munitions. Since 1919 he has been Professor of Chemistry in the University of London (Queen Mary College). He has published numerous papers and books on inorganic and physical chemistry, thermo-dynamics, the alkali industry, the specific heats of gases, and chemical mathematics. Has a wide knowledge of the history of chemistry, to which subject he has extensively contributed. His *Origins and Development of Applied Chemistry* covered the vast field of the hitherto unexplored prehistory of chemistry.

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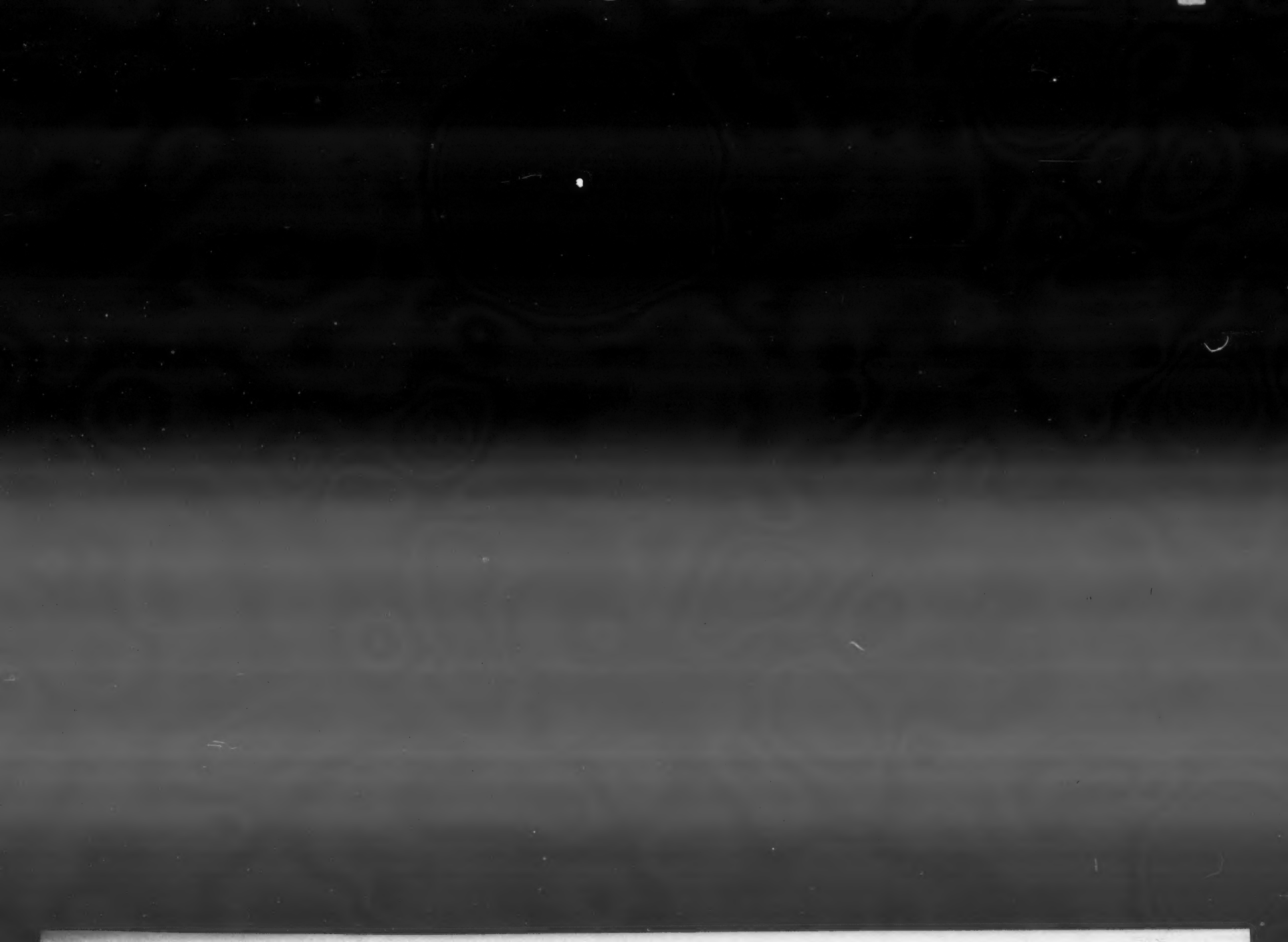
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